THE COCHRAN BOOK

OF

OIL-FIRING.

By W. K. WILSON, B.Sc., Wh.Ex.

PART I. - - - OIL FUEL AT SEA.

PART II. - - - OIL FUEL ON LAND.

COCHRAN & CO., ANNAN, LTD.,
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PLEASE READ THIS.

Our reason for publishing this book is that our experience has shown it will be welcome. Yet, though this is so, one or two additional words of explanation can not be out of place.

The book is not a piece of "special pleading" concealing an advertisement. It is a genuine attempt to give a practical account of "Oil Firing," as applied to the purpose of steam raising in boilers at sea and on shore. Of course, the Cochran Patent Vertical Multitubular Boiler finds a well-deserved place in its pages, but the discussion of the subject is sufficiently general to make it useful to all boiler owners. Comment, and corrections, will be welcomed.

The Author is not a member of our staff, and has had a perfectly free hand in the treatment of his material, except in so far as lack of space has prevented him from dealing with all the kinds of "burner" on the market. That he has only described in detail two or three typical ones must not be taken to mean that we consider them only to be practical. Our Boilers are at work with many different designs of burner and with various systems of atomizing the oil, and it is for the owner of the boiler under consideration to examine the evidence of the various makers of oil-firing gear in support of their burner and plant, and then to give his verdict accordingly. We are satisfied that our boiler will do its part creditably.

COCHRAN & CO. (ANNAN), LTD.

Annan, Scotland,
July, 1921.

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SECTION 1.

The Advantages and the Disadvantages of Liquid Fuel.

The earliest records relating to a practical system of using Liquid Fuel for steam production are found in a paper read before the Institution of Mechanical Engineers in 1884.

During the 37 years which have elapsed since then, progress in attaining increased efficiency, and in simplifying apparatus, has been rapid.

The purpose of this little book is to give a brief account of the development of oil-burning systems, and to describe in some detail a modern "pressure" installation.

In common with a host of other important discoveries, the greatest obstacle to progress has been ignorant prejudice, as well as an attitude of mind strongly resembling the dog in the manger.

Mechanical difficulties are readily overcome if the basic idea is sound, whilst financial considerations generally adjust themselves in course of time.

But prejudice is totally different to either of these, and must be combated by other weapons.

In the case of liquid fuel, dogged perseverance, and a truly British determination to succeed, have placed the fruits of victory within reach.

To-day, there is hardly a single branch of industry where the adoption of liquid fuel would not yield considerable advantages, and the near future should see these advantages greatly magnified.

An instance of the benefits which are lost through sheer ignorance, prejudice, or conservatism (call it what you will), may be illustrated by the liner *Mauretania.*

Nine years ago it was estimated that by installing liquid fuel in place of coal the following advantages would have accrued: a reduction in number of over 250 of the stokehold staff, a saving of 100,000 cubic feet of space, and various minor advantages which will be mentioned later.

The net gain was estimated at no less than a quarter of a million sterling a year, yet so great was the distrust of new methods, that every furnace in the vessel was fitted for burning coal.

A small portion of the penalty exacted for this shortsighted policy was brought to public notice quite recently, when a brief note in the daily press announced that the *Mauretania* had been delayed in port for over thirty hours owing to a temporary breakdown of the coaling appliances.

The large shipping companies, however, are beginning to realise the benefits attached to oil-fired furnaces, as evidenced by the large number of vessels being refitted with this end in view, of which perhaps the most notable example is the giant Cunarder, *Aquitania.* The number of firemen in this ship is now 42, as against 320 with coal firing.

This, of course, is in keeping with the present great need for economy. We cannot now afford to neglect any opportunity which will enable materials to be used to their utmost capacity. Our old-fashioned conservatism is becoming too expensive a luxury.

Looking at the question of the value of liquid fuel as an agent for raising steam from an impartial standpoint, there are several well-defined advantages. There are also, at present, a few equally well-defined disadvantages.

We will examine, briefly, a few of these items.

1. Oil Possesses Superior Evaporative Power.

More heat is stored in a given quantity of oil than in the same quantity of coal. In rough figures, one pound of coal, possessing a heating value of 14,500 B.T.U., will evaporate 10 lbs. of water from and at 212 degrees Fah. One lb. of fuel oil, on the other hand, having a calorific value of 19,000 B.T.U., will evaporate 15 lbs. of water from and at 212 degrees Fah.

We have, then, that 10 lbs. of oil possess the same heating capacity as 15 lbs. of coal.

In terms of output, practice yields the following figures :—*One lb. of oil* is required per I.H.P. per hour, whilst under similar conditions, the same power output demands the expenditure of at least $1\frac{1}{2}$ *lbs. of coal.*

The above figures are based upon the performance of a modern triple-expansion engine developing about 3000 I.H.P.

For an engine of this size, then, the oil consumption would be about 32 tons per day, whilst the coal consumption for the same period would be no less than 48 tons.

If the questions of relative costs and of saving in space are neglected, for the present, the above figures show that there are sixteen tons less rubbish to be dealt with every day when burning liquid fuel.

This gives a direct saving in stokehold labour, and prevents the stokehold from becoming a dumping ground for waste material.

2.—Saving in Bunker Space.

The increased calorific power of oil is responsible for an appreciable saving in the space occupied by bunkers.

This saving can be expressed as a gain in cargo-carrying capacity, or it may serve to increase the radius of action of the vessel.

The first consideration is of vital importance to merchant steamers, whilst the latter advantage is of special importance when speaking of naval vessels.

The gain in space is not wholly represented by the increased calorific power of oil, as the following figures will shew :—

> One ton of oil, specific gravity 0·9, occupies 39 cubic feet.
>
> One ton of coal occupies 45 cubic feet.

Assuming that a 10,000 ton ship, with engines developing 3000 I.H.P., makes a 14 days voyage, the oil bunkers would weigh 450 tons, and would occupy 17,550 cubic feet of space.

Under exactly similar conditions, coal bunkers would weigh 675 tons, and would occupy no less than 30,375 cubic feet of space.

These figures shew a saving of 12,825 cubic feet of space when burning oil.

Another important factor tending to increase the efficiency of an oil-fired ship is the fact that there is a noticeable increase in speed when oil is substituted for coal.

This is largely due to the absence of all necessity for opening furnace doors to clean or replenish fires.

The full head of steam is constantly maintained, even

in the Tropics, where the efficiency of the stokehold staff is liable to deteriorate owing to the intense heat. (Temperatures of 115 to 125 degrees Fah. have been recorded.)

Finally, it should be noted that oil may be stored in spaces which are usually regarded as idle, *e.g.*, the double bottom.

But it must be borne in mind that the saving in space resulting from this possibility is modified by the consideration that coffer-dams are required to surround the oil storage tanks, to isolate them from other parts of the vessel. This reduces the risk of fire, and prevents damage to cargo through oil leakage.

3.—Reduction in the Cost of Handling.

In these days of high wages and short hours, this item deserves particular attention.

A little reflection will shew that, on the score of labour charges, oil has the advantage all along the line.

Right back in the oil fields this advantage begins. Proportional to the immense variety of products yielded from the refineries, the labour involved is very much less than that required to win coal.

At the oiling wharfs, the labour required to fill a ship's bunkers with oil is only a small fraction of the work involved in coal bunkering. It is true that the operation of taking in coal has been considerably speeded up by the introduction of mechanical appliances. But the ports at which these are available are not numerous, nor is the cost of attendance and upkeep a negligible item.

Contrast the roar, bustle, dirt, and inconvenience

connected with coaling operations, with the perfectly simple and silent method of filling an oil storage tank.

This latter operation merely calls for the attachment of a feeder pipe to the ship's tanks and the whole supply of fuel for the voyage is shipped—as easily as the fresh water tanks are replenished.

In special circumstances, the fuel supply can be augmented at sea or whilst lying at anchor.

The removal of all discomfort due to the necessity for calling at intermediate ports for coal is a decided advantage on passenger steamers.

To the shipowner the reduction in stokehold staff will represent perhaps the biggest saving in labour costs.

To many who have had no sea experience with an oil-fired plant, the array of appliances introduced to burn the oil may afford a suggestion of complication.

One voyage is sufficient to remove this misconception. An oil-burning plant requires far less unskilled attention than coal.

The truth of this statement is well illustrated by the experiences of certain sections of the Army in Egypt.

The supply of Arab labour was of such a low intellectual standard as to be absolutely incapable of handling a shovel. Oil fuel was installed, with the result that the full head of steam was always available, with only one man in attendance on the boilers.

At sea one fireman can control the fires in twelve furnaces, and then have enough time on his hands to keep the stokehold clean.

The absence of a heavy demand for unskilled labour

does not imply that there is a heavy demand on the skilled attention of the Engineer-in-charge.

Provided that the several units of the system are kept in proper working order and all duplicate fittings are available for immediate use, the engineer on watch will only be called in to open a valve here, or close one there, to keep a balance between the various temperatures and pressures recorded by the gauges. The inevitable duty of correctly attending to the water level in the boilers is more exacting than the demands of the entire oil-burning system.

With regard to upkeep, the vital parts of the plant, such as the filters, fuel heater, and fuel pump, are fitted in duplicate. There is thus always time for effecting repairs at leisure.

No time must be lost, however, in making good any damage. To have all duplicate apparatus in proper working order is the only effective way of eliminating the possibility of a serious breakdown.

4.—Cleanliness.

The absence of dust, ashes, and clinker is to the stokehold staff one of the most gratifying features of an oil-burning installation.

Apart entirely from the question of efficiency, there is nothing more distasteful to the conscientious engineer than the necessity for carrying out his duties in dirty surroundings.

The presence of fine particles of grit is also dangerous to machinery. A minute speck of dust may find its way into a bearing. Cases could be cited in which a total stoppage of the engines was due to this cause alone.

There is also the liability for gauge glasses and dials to receive a coating of grime; this may result in making them unreadable, or, which is worse, in introducing the danger of false readings.

In general, cleanliness is found to be one of the most potent aids to efficiency. It is rarely that one finds slackness and inefficiency running parallel with a clean and orderly engine or boiler-room.

5.—Ease of Control.

The engineer in charge has at all times perfect control over the steam-producing power of his boilers.

The principal reason for this is, that only sufficient fuel is introduced into the furnace at any time to supply the needs of the moment. The supply can, therefore, be instantly checked by simply turning a valve hand-wheel.

Contrast this with the dust and racket of a coal-fired furnace, where a great bulk of fuel is in operation at once and the supply is regulated by the shovelful.

This matter of control over fires is of great importance when entering or leaving harbour. The fires can be readily adjusted to follow the manœuvres of the ship. This will relieve the boilers, steam pipes, and fittings from undue strain produced by constant blowing off.

6.—More Equal Heat Distribution.

Oil enters the furnace as a fine conical spray, which bursts into flame at from six to eight inches from the end of the burner.

With modern atomizing systems, the nature of the flame produced is such that practically all the oil is con-

sumed in the air space of the furnace. This eliminates the possibility of liquid oil being deposited on the furnace plates, so that the surfaces of the plates are rarely protected by firebrick linings in modern boilers.

The absence of these linings, together with the entire elimination of fire-bars and arches, enables the whole interior of the furnace to be used for combustion.

Thus a gain in heating surface is made, and the temperature is practically uniform throughout the furnace.

The temperature in the furnace would be about 2600° F.

The top of the furnace being at the same temperature as the bottom, better circulation is promoted, with a consequent increase in steam-raising efficiency. Moreover, the absence of any need for opening furnace doors prevents the admittance of blasts of cold air to the hot interior of the furnaces.

This eliminates strain on the boilers due to unequal expansions and contractions.

In making the above remarks, we have in mind the Scotch type of Marine boiler. The question whether linings shall or shall not be used in the furnaces of other types of boiler depends entirely upon the design of the furnace. In the Cochran Boiler, for example, brickwork is provided in the furnace to protect the lower circumferential seams, but here, the design of the furnace is such that the presence of firebrick for this purpose does not materially reduce the space available for combustion.

7.—Cost.

The world's production of fuel oil is not yet so extensive as to lower the cost to the same level as coal.

There is no reason to doubt, however, that the present increased demand for oil for all purposes will stimulate production to such an extent that the future will see the price of oil as low, or even lower than the price of coal.

It is very difficult to quote exact figures for the relative prices of fuel oil and coal, but some information is given on pages 104 to 108.

Much depends upon the locality in which the purchase is made. Oil purchased in the British Isles, for instance, may cost from two to three times as much as coal. If the increased heating capacity of the oil is taken into account, oil bunkers may cost twice as much as coal, but this depends largely on the bunkering port.

Vessels trading regularly to the oil fuel regions are in a much happier situation, with regard to bunkers, than those which have to depend upon home supplies. Fuel oil may be purchased near the oil fields at a price which is considerably below that of coal. Tank steamers are particularly favoured in this respect, and it is found to be a paying proposition to take in sufficient oil at the outward end of the voyage to last a double journey.

The great saving in labour which results from utilising oil fuel has already been dealt with. This is a factor likely to exert a considerable influence on the relative costs of coal and oil.

The labour connected with the production and consumption of oil is much less than with coal, but whilst coal is practically free from transport charges, oil suffers materially in this respect. This aspect of the matter is dealt with in the next paragraph.

8. Distribution.

The means of distributing oil over the world is, at present, far from adequate. Nature has been almost as liberal with her oil deposits as she has been with coal. Vast natural reservoirs of oil are scattered freely throughout the world, and it remains for man to devise proper means for tapping them, and for storing the rich harvest which will be released. The question of transporting the oil from the oil fields to seaboard also requires special consideration, and the solution of this problem, be it noted, is in some respects much simpler than with coal. Whilst coal requires a complete railroad equipment for transporting it in bulk, oil may be conveyed almost any distance along pipe lines.

Examples of this are to be found in the wonderful trunk lines of America, which convey oil for hundreds of miles across open country; whilst, nearer home, there is the pipe line recently installed between Glasgow and Rosyth, which is capable of feeding ships with oil at the rate of 100 tons an hour.

We can take for granted, then, that there is oil in abundance, but that the facilities for distribution are not yet adequate. The factor necessary to stimulate activity in providing these facilities is a suitable demand.

There can be little room for doubt that this demand is becoming more insistent every day.

When the distribution of oil has been properly adjusted prices should attain a uniform level all over the world, and bunkers will be as cheap in England as on the American coast. This ruling price should compare favourably with the price of coal, and there will then be no room for doubt as to the greater economy of liquid fuel.

9.—Fire Hazard.

Fire is an elusive element. Fire hazard depends greatly upon the human factor. Negligence is the chief cause of fire. It is also the cause of many other accidents apart from fire.

The real danger from fire is present when using oils which contain a big percentage of volatile gases.

Crude oil contains these volatile constituents, but residuum may not.

The first fire precaution, then, is to ensure that the oil does not contain a dangerous percentage of these volatile constituents. This safeguard is easily applied by stipulating that the oil must not have a higher flash-point than what has been proved to be safe in practice.

It should be remembered, however, that this limiting temperature must not be fixed any higher than necessary, or poor spraying properties will result.

The flash-point is required to be not less than 175 degrees Fah. in the Navy, and 150 to 160 degrees Fah. for the Mercantile marine.

It should be noted that fuel oil, unlike coal, contains no power for spontaneous ignition.

Dynamite has been exploded in a reservoir of this oil (flash-point 240 degrees Fah.) without causing ignition.

Systematic inspection for leakage, rigid cleanliness, and careful attention are the remaining essentials to provide a proper insurance against fire.

It is interesting to note that a proposition has been brought forward for using solid oil. Experiments are being carried out with this type of fuel, and if these are successful, we may look for even greater security from fire, both in storing and in handling oil, in the future.

SECTION 2.

Fuel Oil.

Petroleum is a natural product which has a wide distribution throughout the world.

It is possible that oil deposits originated from animal or vegetable matter deposited with a mineral sediment, but the exact origin of petroleum is still a matter for speculation.

Oil deposits are found in the interstices of porous strata, such as sands, sandstones, and limestone, and the location is generally overlaid by an impervious covering of clay or compact shales.

The presence of an oil well may be indicated by the nature of the surrounding country. Thus, an escape of natural gas from the surface of a location, or from small mud volcanoes, is usually a good indication of the presence of oil.

The oil is tapped by sinking a well. This operation is, in some cases, a matter of great difficulty and expense, owing to the great depth which separates the oil pocket from the surface.

Perhaps the most widely used boring system in America is the Percussion process.

A square wooden tower is erected over the point at which sinking is to commence. Heavy drilling bits, ranging in diameter from 26 ins. down to $4\frac{1}{2}$ ins. are suspended centrally from the top of the tower by stout wire cables.

A rapid up-and-down motion is given to the bit, which pulverises the ground and reduces it to mud. This action

is assisted by pouring water on to the bit. When drilling has proceeded a few feet, the bit must be withdrawn, and the loose earth removed from the hole by means of a cylindrical can, called a bailer.

If the ground is very loose, and the well is to penetrate deep, it becomes necessary to support the walls of the bore by steel linings. These lining tubes diminish in diameter as the well becomes deeper.

Thus, to drill a hole 2000 feet deep, the bore might be 36 ins. in diameter at the surface, gradually diminishing as the well deepens, until it has become reduced to 4 ins. at the bottom.

On penetrating oil-bearing strata, the natural gas which is sometimes imprisoned with the oil, forces large volumes of oil to the surface. This type of well is known as a "gusher."

A "gusher" out of control is dangerous, both to the boring gear above the well and to surrounding property.

When the oil is not forced to the surface naturally, mechanical appliances must be brought into operation.

The simplest of these is a steel bailing can, which is lowered down the well by a winch. Alternatively, the oil may be lifted by lowering a pump, or by releasing compressed air at the bottom of the bore (the air lift pump).

The crude oil is conveyed from the well to large reservoirs, where sandy particles, mud, and paraffin wax are allowed sufficient time to settle.

From the settling tanks, the oil is pumped into the first boiler or still, and the refining process begins.

First, the more volatile constituents are removed by distillation, to be condensed in separate chambers. The

lighter oils obtained in this manner include petrol, benzine, benzolene, and naphtha.

By carrying the process of distilling forward until "cracking" or disintegration by heat takes place, lamp oil and paraffin are obtained, leaving a heavy oil called residuum.

From residuum, lubricating oils are manufactured, the final residue being solids such as paraffin wax, ash, and traces of metals.

The oils used as fuel for steam production range in quality from the crude oil of nature to the residuum left after the crude oil has passed through the refinery. The quality of fuel oil depends, then, upon the extent to which it has been refined, the most noticeable difference between different qualities being in respect to specific gravity.

Burmah oil, for example, may have the following chemical composition: 86 per cent. carbon, 12 per cent. hydrogen, 1½ per cent. oxygen, and the rest impurities, chiefly sulphur. This oil will flash at about 200 degrees Fah., and have a calorific value of 18,800 B.T.U. per lb. The specific gravity will be 0·92.

An analysis of Russian petroleum, on the other hand, may yield the following figures: 85 per cent. carbon, 14 per cent. hydrogen, no oxygen, and the rest impurities. Other characteristics are, flash-point, 120 degrees Fah.; calorific value, 20,000 B.T.U. per lb.; specific gravity, 0·82.

In general, low specific gravity indicates low flash-point, owing to the greater ease with which the lighter oils may be vapourised.

Within the safe limit of flash-point already specified, however, low gravity oils will give the best satisfaction

in practice, especially in cold climates where there is a liability for the oil to congeal.

An average sample of fuel oil in general use yields a specific gravity of 0·90 and a flash-point of about 180 degrees Fah.

Fuel oil is deep brown in colour, and gives off a certain amount of heavy vapour easily detected by its pungent odour. The oil is viscous, and requires, as a rule, to be heated prior to spraying.

The world's production of crude oil exceeds 90,000,000 tons per annum, and experts do not hesitate to say that this quantity could be increased to meet almost any demand.

The principal oil fields are in the United States of America and in Mexico.

Second place is taken by the Baku district of Russia, though the Russian oil fields suffer from bad transport facilities.

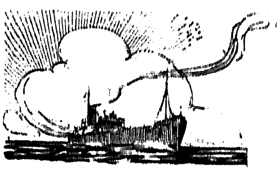
Other Continental countries which contribute to the world's supply are Roumania and Galicia.

Turning to the Far East, Burma and Japan are known to hold huge stores of oil.

The whole of the British Empire only contributes about 2½ per cent. of the world's oil supply. The principal oil fields are in Trinidad, New Zealand, and South Africa. Some authorities state that if the Colonial oil fields were fully developed they could supply England with all the fuel she requires.

Experimental borings are being made at the present time in the British Isles. A limited degree of success has been achieved at certain wells, but progress is hampered by lack of materials.

There can be no doubt that if oil were found in England in commercial quantities, a huge national prosperity would be built up from this source alone. Oil may, even yet, bring the same prosperity to England in the twentieth century that coal produced in the nineteenth.



SECTION 3.

The Combustion of Oil.

An efficient oil-burning system must provide for continuous and complete combustion of the oil, combined with perfect control over fires, so that men and property shall not be exposed to danger from fire.

When an oil containing inflammable constituents is heated, three stages are passed through before complete combustion takes place :—

1. Vapourising point.
2. The Flash point.
3. The Burning or Fire point.

The Vapourising point, or, as it is sometimes called, the smoky point, is the temperature at which a perceptible vapour leaves the surface of the oil.

The Flash point is the temperature at which a mixture of oil vapour and air will take fire upon applying a light. The flashing which occurs is intermittent, consisting of small flashes of flame when sufficient vapour has collected.

The Burning point is about 40 degrees Fah. higher than the flash point in the case of petroleum. It is the temperature at which intermittent flashing gives place to continuous burning.

The first condition necessary for burning oil can now be stated :—

> "The oil must be at a sufficiently high temperature for vapour to be released in sufficient quantities for continuous combustion."

This by itself, however, is far from sufficient to give efficient, or even safe, combustion.

Another factor upon which efficiency largely depends is the regulation of the air supply.

An abundant air supply will not in any way assist

towards proper combustion—indeed, it will probably result in a dangerous explosion.

The importance of this matter of correct air supply is very well pointed out in the words of a well-known authority on liquid fuel :—

> "It were better to feed oil to the furnaces by the shovelful, and have a proper air supply system, than to be possessed of the most perfect atomizers and have bad air regulation."

It is interesting at this point to digress a little and examine what the process of burning coal can teach us. Such an examination may shed a useful sidelight upon the principles behind an oil-burning system.

A fire composed of lumps of coal is full of small cracks and air spaces. Thus, the actual area of fuel exposed to the air is very much larger than the superficial dimensions of the fire grate. There is, then, no great difficulty in bringing the air required for combustion into intimate contact with the fuel, and combustion is fairly efficient.

Coal is burnt in three stages :—

1. The fuel is heated by the red-hot burning coal surrounding it. The more volatile constituents are driven off, the latent heat of vaporisation being derived from the surrounding fuel. This is a process of distillation.
2. The gas evolved in stage 1 travels to some distance away from its place of origin, and then burns.
3. The solid carbon remaining behind, after all the volatile constituents have left, is no longer cooled by the abstraction of heat for vapourisation purposes. It is therefore able to attain a sufficient temperature for combustion to take place.

Combustion under the circumstances outlined above occupies a certain interval of time.

Now, it is a well-recognised fact that if the speed of combustion be increased there follows a corresponding increase in efficiency. To verify the truth of this statement, we need only refer to certain experiments connected with the development of the internal combustion engine. These experiments shewed plainly that the speed of combustion was an all-important factor in determining the efficiency of the machine.

Engineers were not slow to realise the advantages which could be obtained by speeding up the process of burning coal. Thus, several years ago, a system of burning coal was introduced with this end in view.

The basic idea of the system was to reduce the coal to powder before introducing it into the furnace. By doing this it was easy to surround each particle of coal dust with the correct amount of air for complete combustion. Thus the speed of combustion would be greatly accelerated.

Practical difficulties, however, prevented this method from being adopted for steam-raising purposes, although many modern blast furnaces are constructed to work with powdered coal as fuel. The principal objections to the extensive use of powdered coal are :—

1. A special plant is required to pulverise the coal.
2. The residue produced by the non-combustible constituents is liable to choke passages, and special dust catchers are required to prevent the escape of grit into the atmosphere.
3. The ever-present danger of explosion.

At a later date, when oil fuel had passed through its initial trials, pulverised oil was found to possess just those qualities which were lacking in coal. Oil may be pulverised

by very simple apparatus. It leaves no solid residue if the plant is working properly. It cannot ignite spontaneously.

In passing, it is interesting to note that the earliest attempts at burning oil were modelled exactly on the existing methods employed for coal.

The oil was spread out in shallow troughs so as to expose a large surface to the air. Heat was applied to the oil until the ignition temperature was reached. At this stage the firemen were usually forced to retire to a safe distance until the conflagration subsided. The attendants had no control over the fire.

The reason for this initial failure was not far to seek. It was due solely to the presence of too much fuel in the furnace at once. In the case of coal, this same objection holds. But with solid fuel the process of combustion is so slow that there is generally plenty of time to exercise control.

The final stage in the development of liquid fuel began when the notion of attempting to burn oil in bulk like coal was given up, and the thoughts of experimentists turned to the idea of using pulverised oil.

The success of this latter system of burning oil is so great, that to-day there is every indication that it may ultimately displace coal altogether.

The third factor, then, which must enter into the construction of an oil-burning system is :—

> " The oil must be properly atomized, so that each particle of oil is surrounded by a sufficient quantity of air to ensure complete combustion."

Three Laws.

1. The oil must be at a temperature sufficient to ensure continuous burning.
2. The oil must be properly atomized.
3. The air supply must be properly regulated.

There are three principal methods of atomizing oil:

1. Steam atomizers.
2. Air atomizers.
3. Pressure atomizers.

There are many points of similarity between air and steam atomizers. In both cases the oil is pulverised through the agency of a second fluid, which may be called, therefore, the atomizing agent.

In the case of steam atomization, however, no separate fuel heater is required, and the oil may be fed to the burners by gravity.

In pressure systems of atomization, an oil spray is produced without the aid of a second fluid. The air intakes into the furnaces may, however, be arranged to assist atomization as much as possible.

A good atomizer must be able to produce a soft, voluminous flame which will fill the furnace without allowing any intense blow-lamp-like flame to play upon one portion of the furnace plates.

The process of combustion should be so complete that no liquid oil is deposited upon the furnace plates.

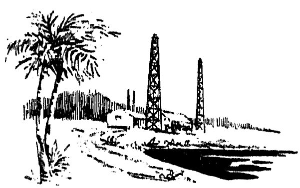
With poor atomization, as in the early days of oil-burning appliances, it was necessary to protect exposed portions of the furnace plates with firebrick linings. It was then quite common to find the whole interior of a fur-

nace choked up with firebrick. This naturally reduced the efficiency of the heating surfaces, obstructed the furnaces, and appreciably reduced the combustion space available.

The efficiency of modern atomizers has almost eliminated the necessity for linings. This is especially the case with large-sized marine boiler furnaces. There are, however, certain types of boiler in which the presence of a firebrick lining in the furnace is necessary to protect the boiler structure from intense local heating. In the Cochran Boiler, the lower circumferential seams are protected by a ring of firebrick, so arranged that the capacity of the furnace is not materially diminished. The presence of this firebrick also serves the useful purpose of retaining sufficient heat to re-light the burners should a temporary stoppage occur.

The function of an atomizer is, then, to enable oil to be burned like gas, to be economical in operation, and to be simple in design.

The last two items are not always easy to harness together.



SECTION 4.

Atomizers.

1. Steam Atomizers.

Fig. 1 shows a simple type of steam atomizer used in locomotive practice.

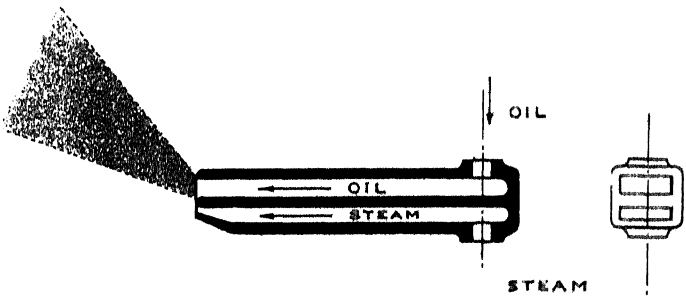


FIGURE 1.

SIMPLE STEAM ATOMIZER.

The spray produced is flat, and spreads out like a fan.

Oil enters the top chamber, and is heated on its way to the exit orifice by steam, which flows along the bottom chamber.

The steam passage is narrowed at exit, and slopes upward to meet the oil stream.

Atomization occurs when the high-velocity steam jet intercepts the oil.

The steam should be superheated to prevent the formation of moisture.

Fig. 2 shews another type of steam atomizer, in which atomization is assisted by erecting a brickwork baffle in the furnace. This baffle intercepts the spray and helps to break any particles of oil which may be held in suspension.

The principal disadvantage to be charged against the use of steam as an atomizing agent is the rather heavy water consumption entailed.

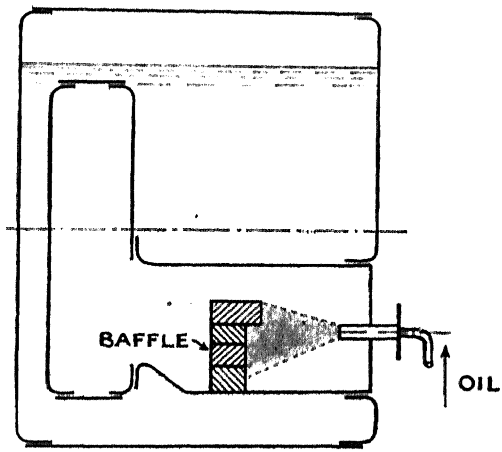


FIGURE 2.
ATOMIZER WITH BRICKWORK BAFFLE.

The water used to effect atomization is not recoverable, and must be replaced by pumping fresh water into the boilers.

At sea, fresh water is a precious commodity, and a loss of 5 per cent.—some authorities say 12 per cent.—of the fresh water supply for atomization purposes is a matter for serious consideration.

For every 100 lbs. of water evaporated, about 5 lbs.

are required for atomization. Thus, a ship fitted with engines developing 3000 I.H.P. would consume over half a ton of fresh water per hour.

Two points in favour of steam atomization are first, the simplicity of the apparatus employed; and second, the very good spray which is obtained.

With modern pressure burners, however, oil sprays are obtained which are quite as good as any obtained by using steam or air as atomizing agents.

For many years a serious disadvantage with steam atomizers was the difficulty of lighting up when no auxiliary steam supply was available.

This disability has now been removed, a large number of Cochran Boilers having been installed with the ordinary steam jet atomizing equipment, supplemented by a simple apparatus to enable the boiler to be started from cold.

This apparatus consists of a small auxiliary pressure jet burner, and a hand-pump for maintaining pressure.

The burner is in the form of a simple U tube with a pressure jet nozzle and a hook for attaching waste. The waste is soaked with paraffin and lighted, the burner is then pushed into the furnace, and the hand-pump started, the connection between the hand-pump and the burner being made by flexible metallic piping.

With this apparatus it is possible to raise sufficient steam in a 7-ft. diameter boiler, by means of the hand-pump, to start the main steam jet burners in about 40 minutes from cold water.

2. Air Atomizers.

Fig. 3 shews the principle upon which nearly all air atomizers function.

The sprayer illustrated in Fig. 3 will no doubt be recognised in any of the following forms :—

Scent-sprayer.
Garden spray.
Blow-lamps.
Painters' spray.

The principle is the same as already described for the steam atomizer, viz., a blast of air (or steam) moving at high velocity across the open end of the vertical pipe

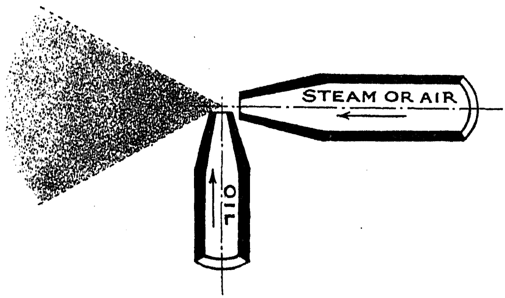


FIGURE 3.
"SCENT-SPRAY" ATOMIZER.

produces a sufficient reduction in pressure at that point to cause a ready flow of oil up the pipe. When the oil reaches the top of the pipe it is blown into a fine cloud by the air blast.

Air atomization has found a certain amount of favour for marine use.

The air pressure may vary from 15 to 20 lbs. per sq. inch, whilst in modern systems, using hot air, the pressure may be as low as 3 lbs. per sq. inch.

These pressures are easily maintained by a single-stage compressor. Moreover, the compressor requires no cooling

arrangements, since it is good practice to introduce hot air into the furnaces, and hot air will cool considerably in expanding into the combustion space.

About 1 lb. of air is required to atomize 1 lb. of oil, the air pressure being about 20 lbs. per sq. inch. This represents a consumption of about $2\frac{1}{4}$ per cent. of the total power.

The steam used for driving the compressor, and for heating the oil, is not lost, since it can be condensed and returned to the boilers. The use of air as the atomizing agent, therefore, entails no loss of fresh water.

The aim of the designer of an air atomizer is to produce a burner which will give an efficient spray by using large volumes of low-pressure air.

The introduction of this air into the furnaces would then effect a double purpose. First, it would atomize the oil; and second, it would materially assist the draught arrangements in supplying the air necessary for combustion.

3. Pressure Atomization.

Perhaps the simplest type of pressure atomizer to be found is the ordinary garden syringe.

The oil is atomized by being forced, under pressure, through properly arranged channels. A fine, cloud-like spray is obtained by imparting a rapid, whirling motion to the oil just before it emerges into the furnace. By paying proper attention to the manner of producing this whirling motion it is sometimes possible to work with lower oil pressures, thus relieving the burners and pipes from a certain amount of strain.

Atomization is further assisted by properly controlling the air supply to the furnaces. Thus, the air intakes may be arranged to impart a spiral motion to the air as it enters

the furnace. This assists atomization by promoting an intimate mixing of air and vapour.

The size, shape, and disposition of the oil passages in pressure burners have a considerable influence upon the kind of spray produced. In practice a conical, divergent spray is found to give the best results in marine boiler furnaces.

Fig. 4 shews a simple type of pressure burner. The

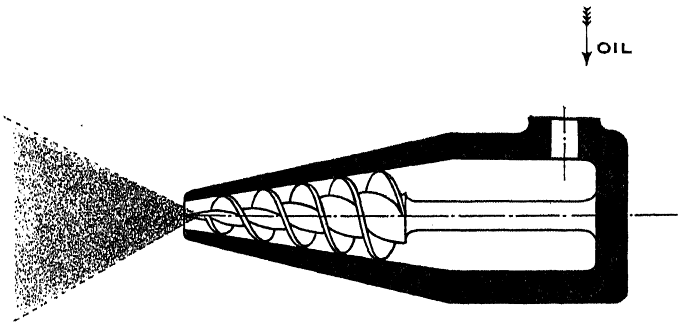


FIGURE 4.

SIMPLE PRESSURE ATOMIZER.

oil is forced round a series of helical threads upon the surface of a cone. Thus a whirling motion is imparted to the oil, whilst the narrowed passage at exit produces an increase in velocity. These two factors greatly assist atomization.

Pressure systems of atomization are employed almost exclusively in modern marine engineering practice.

This is largely due to the reliability and freedom from breakdown of pressure systems.

SECTION 5.

Pressure Systems of Burning Oil—Typical Installations.

Fig. 5 shews a common arrangement of machinery and pipe connections for a modern pressure system of burning oil.

The principal components of the system are:—Suction

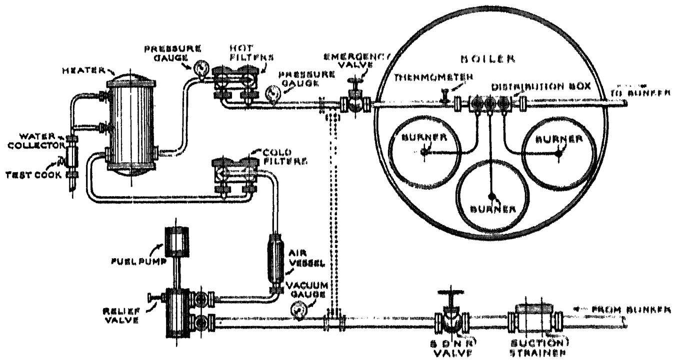


FIGURE 5.

DIAGRAMMATIC ARRANGEMENT OF A PRESSURE SYSTEM OF BURNING OIL.

strainers, fuel pumps, cold filters, fuel heaters, hot filters, distribution boxes, and burners.

Oil is drawn from the bunkers by the fuel pump through the suction strainers. The strainer removes any particles of solid impurity which may be held in suspension in the oil. Choking of the suction pipes and of the pump passages is thus prevented, and a steady flow of oil is assured.

Oil is delivered from the fuel pump under pressure. An air vessel is placed on the delivery side of the pump to maintain a steady flow of oil, and to relieve the system of shock.

Immediately after delivery from the pump, the oil passes through the cold filters. These remove any particles of grit which may have escaped the suction strainer, or have been picked up in the pump.

Some systems dispense with cold filters altogether. This, however, places a heavy strain on the suction strainers, and increases the liability for the oil passages in the heater to become choked.

From the cold filters, the oil passes to the heater. Here its temperature is raised to the proper degree.

During the heating process particles of solid carbon may be formed in the oil, due to a mild form of "cracking." These small particles of carbon would effectively choke the fine passages in the burners, so that means must be provided for clearing the oil of suspended matter after it leaves the heater.

This end is achieved by fitting a set of filters, similar to the cold filters, on the delivery side of the heater. The hot oil passes under pressure through this filter on its way to the burner. This set of filters is, therefore, called the hot filters.

The oil is distributed to the burners by distribution valve boxes on the boiler front.

These boxes contain an independent screw-down valve for each burner. This arrangement allows of any burner being shut down independently.

Finally, the oil passes through the burners, where it is atomized, and issues into the furnaces in the form of a very

fine spray. In the furnace, each particle constituting the spray is completely surrounded by the air necessary for combustion, and the whole bursts into flame at a few inches distance from the orifice of the burner.

The dotted cross-connecting pipe, shown in Fig. 5, is used for circulating the oil during the process of starting the fires. It enables the oil to be circulated through the

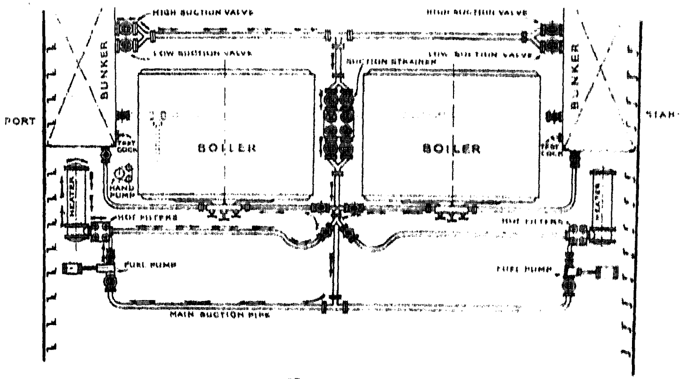


FIGURE 6.

PLAN OF A PRESSURE JET OIL-BURNING INSTALLATION.

heater preparatory to lighting the fires, so that its temperature may be raised the required amount.

Fig. 6 is a plan view of a pressure jet installation, arranged for two boilers.

The oil-burning apparatus, consisting of filters, pressure pump and heater, is in duplicate; the port and starboard sets being cross-connected so that either may be brought in to take the load at short notice.

The importance of keeping the oil free from solid

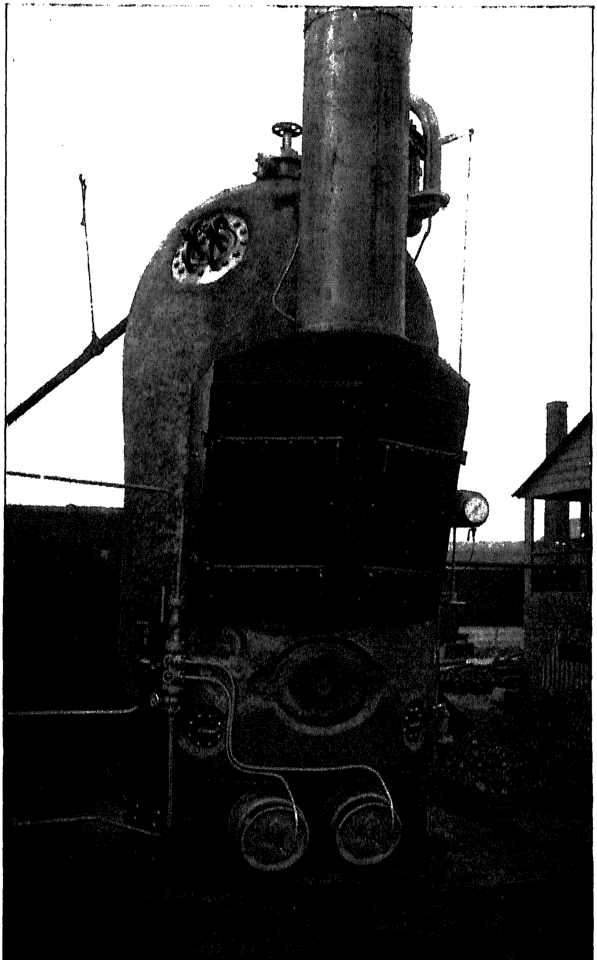


FIGURE 7.
EVAPORATION TEST OF A 7′×14′ COCHRAN VERTICAL BOILER.
(Wallsend-Howden Patent System of Oil Firing.)

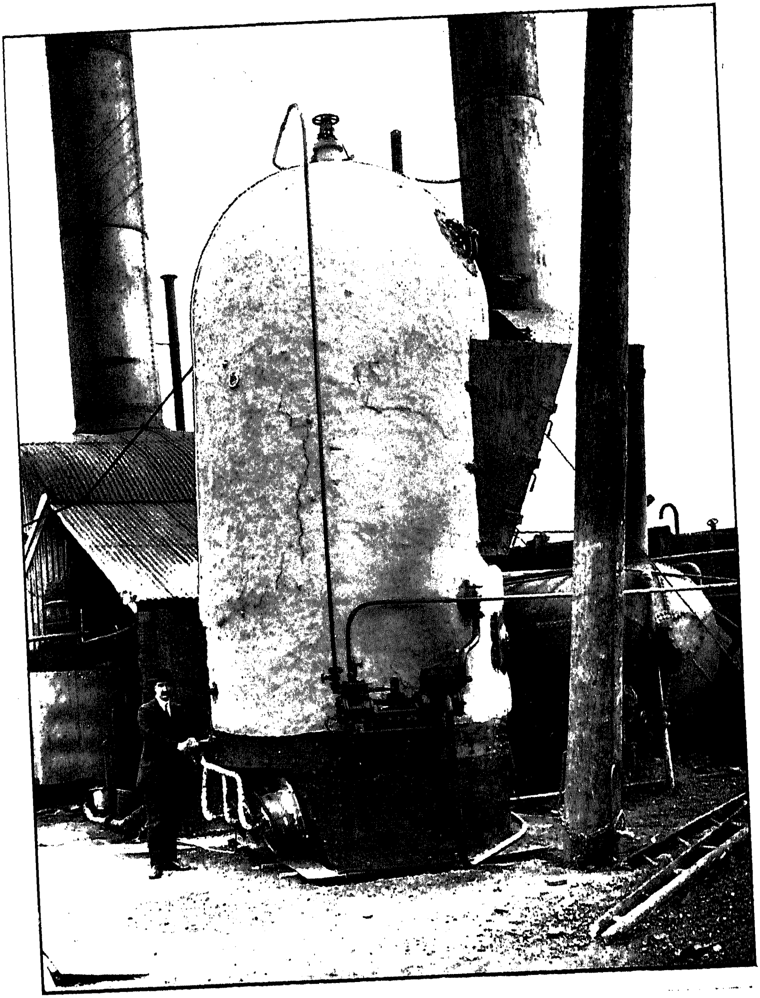


FIGURE 8.

EVAPORATION TEST OF AN 8′ 6″ × 19′ 6″ COCHRAN VERTICAL BOILER.

(Wallsend-Howden Patent System of Oil Firing.)

impurities cannot be overestimated. The many small passages in an oil-burning system are all too easily choked.

In this connection one is reminded of the lazy fireman's definition of a burner diaphragm: "A burner diaphragm is a small piece of steel containing a hole about the size of a piece of grit."

One of the most important duties of the engineer in charge of an oil-burning installation is to keep his filtering system in thorough working order. Improper functioning of the strainers or filters may cause a complete stoppage of the plant.

It is of particular importance when installing new plant to make sure that all dirt and grit has been removed from pipes and passages. The practice of bending pipes by filling them with sand is not recommended when the pipes are to be fitted in an oil-burning plant. Care must also be taken to remove all particles of sand and metal chips from the fuel pump and heater castings.

The vital parts of the system are fitted in duplicate. Parts so fitted include the fuel pump, fuel heater, and every set of strainers or filters.

One set of fittings is therefore always available for immediate service should anything happen to the set then in use.

Several spare burners are also carried to replace working burners which have been removed for cleaning.

Figures 7 to 14 illustrate a few modern oil-burning installations.

Figures 7 and 8 are from photographs taken during evaporation tests of the Cochran Vertical Boiler fitted with the Wallsend-Howden pressure jet system of burning liquid fuel.

The boiler shewn in Fig. 7 is a 7 ft. by 14 ft. standard Cochran Boiler, with two burners firing into the ashpit, which is extended for this purpose, making the total height of the boiler 15 ft.

The boiler shewn in Fig. 8 is larger, being 8 ft. 6 in. dia. by 17 ft. high, and there are three burners firing into the ashpit, which is also extended, making the total height 19 ft. 6 in.

These boilers are rated at evaporations of 3600 and 6600 respectively, but the following results were obtained on trial :—

Size of boiler	7′ 0″ × 14′ 0″	8′ 6″ × 17′ 0″
Heating surface	500 sq. ft.	1000 sq. ft.
Duration of trial	2 hrs.	4 hrs.
Calorific value of oil	19,320 B.T.U. per lb.	18,360 B.T.U. per lb.
Steam pressure	98 lbs. sq. in.	100 lbs. sq. in.
Oil consumption p. hr.	299·5 lbs.	634 lbs.
Water evaporated p. hr.	3550 lbs.	7212 lbs.
Water evaporated per lb. of oil from and at 212 degrees Fah.	14·065 lbs.	13·41 lbs.
Equivalent evaporation per sq. ft. of heating surface per hr.	8·4 lbs.	8·5 lbs.
Thermal efficiency of boiler	70 per cent.	71 per cent.

The true significance of these figures may be realised by comparing them with the following data, which is taken from a paper by D. Brownlie, B.Sc. Hons. (London), published in *Engineering* on 25th July, 1919, entitled :

"Exact Data on the Running of Steam Boiler Plants."

The figures in the column headed "A" are an average for 100 typical colliery boiler plants in Great Britain, whilst the figures in the column headed "B" are an average for 250 typical steam boiler plants, representing 27 different industries in Great Britain.

	"A."	"B."
Type of boiler	87·7% Lancashire	93·5% Lancashire.
Size of boiler	8′ 6″ dia. × 30 ft. long.	8′ 0″ dia. × 30 ft. long.
Fuel	Coal	Coal.
Calorific Value	10,500 B.T.U. p. lb.	11,822 B.T.U. p. lb.
Coal burned per boiler p. hr.	721·5 lbs.	798·8 lbs.
Water evaporated per boiler p. hr.	393·1 lbs.	524·3 lbs.
Water evaporated per lb. of coal from and at 212 degs. Fah.	6·07 lbs.	7·46 lbs.
Duration of test	9·68 hrs.	9·43 hrs.
Steam pressure	86 lbs. p. sq. in.	89 lbs. p. sq. in.
Thermal efficiency of boilers	55·02%	56·71%.

It is at once apparent from these figures, that notwithstanding the claims often made with respect to the efficiency of coal-fired boilers, there is considerable room for improvement; and in this connection it might be mentioned that a coal-fired marine boiler rarely evaporates

more than from 9 to 10 lbs. of water from and at 212 Fah. per lb. of coal. With coal giving a calorifi of 14,500 B.T.U. per lb., this yields an efficiency of cent. This is an improvement on land practice, b not quite come into line with the efficiency obtaine burning oil.

It will be noted that, in both the above boil burners fired into an extended ashpit. Where required amount of headroom is available Messrs (recommend this arrangement. It gives increased capacity, which makes for efficiency, and it is also to arrange a proper brickwork seating capable of a long, continuous, and easy passage for the flan

Where headroom is restricted, however, quit results are obtained by firing through the firehole usual way.

Fig. 9 shews a boiler arranged in this way. A W Howden pressure burner is shewn projecting thro firehole.

Fig. 10 shews a small-size boiler with the oil- equipment dismantled. The hole in the ashpit which the burners project is clearly visible. The above the ashpit may be used as an inspection do may be arranged to carry a special burner for up the boiler.

Fig. 11 shews a boiler with the normal depth o equipped with three Meyer-Smith pressure jet bur

Fig. 12 is from a photograph taken during a s test in the maker's works. The boiler illustrate of a series for installing in hospital barges in Meso and is fitted with Kermode pressure jet burners complete oil-burning installation is also shewn

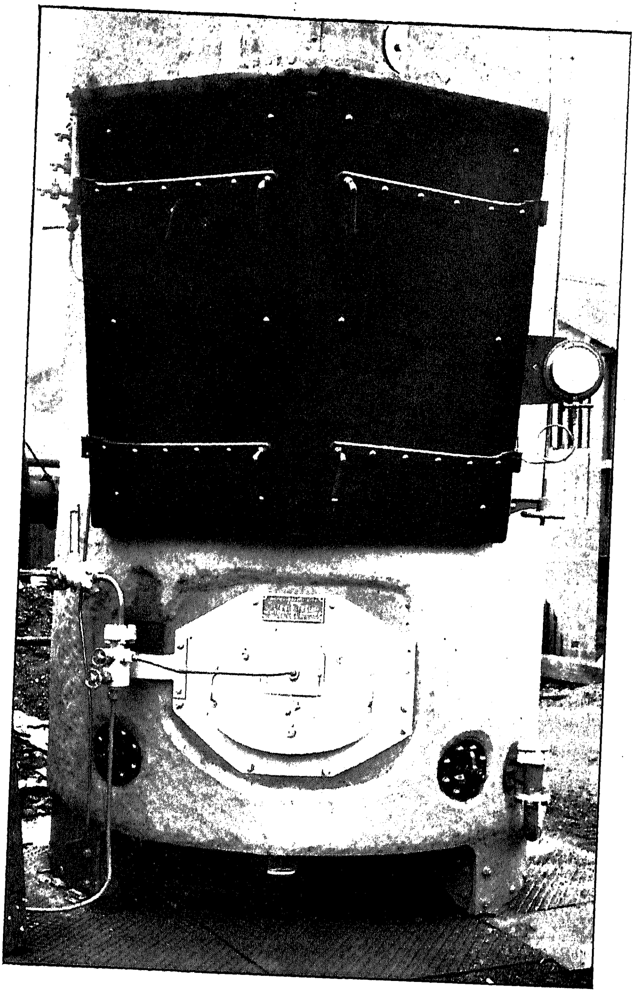


FIGURE 9.
7′ 0″ × 15′ 0″ COCHRAN VERTICAL BOILER WITH STANDARD DEPTH OF ASHPIT, ARRANGED FOR OIL FIRING THROUGH THE FIREHOLE ON THE WALLSEND-HOWDEN PRESSURE JET SYSTEM.

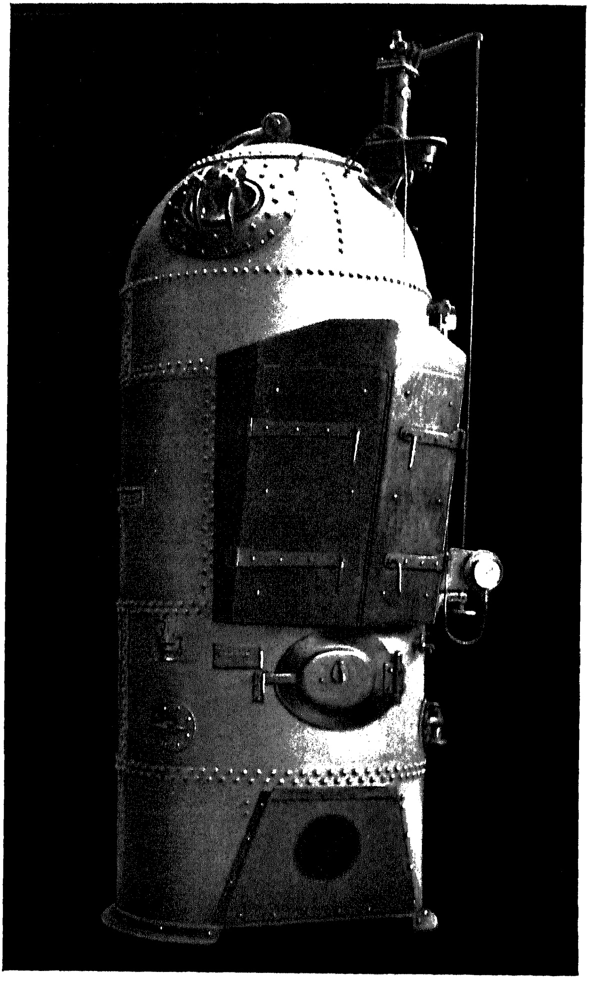


Figure 10.
Cochran Vertical Boiler with Extended "Ashpit" for Oil Firing.

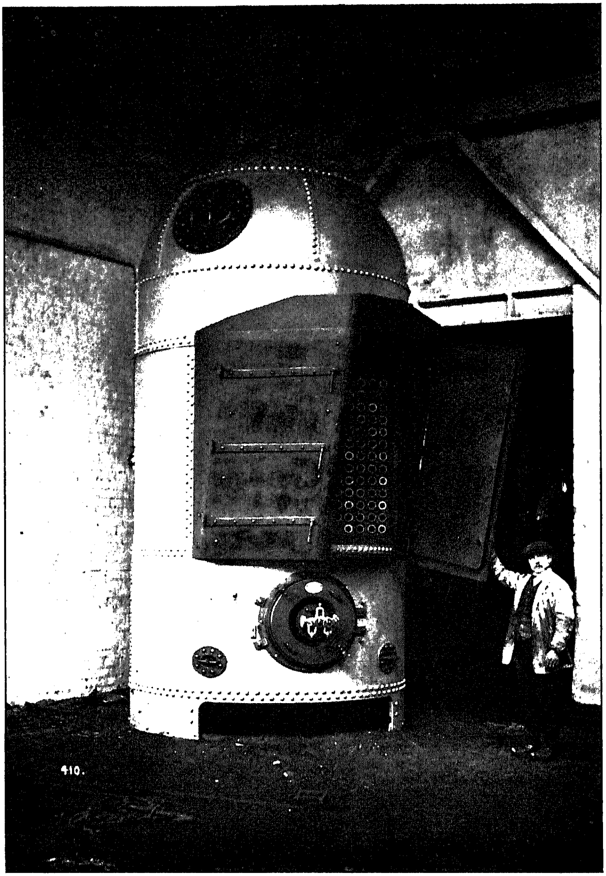


FIGURE 11.

COCHRAN VERTICAL BOILER FITTED WITH MEYER-SMITH PRESSURE JET BURNERS FIRING THROUGH FIREHOLE.

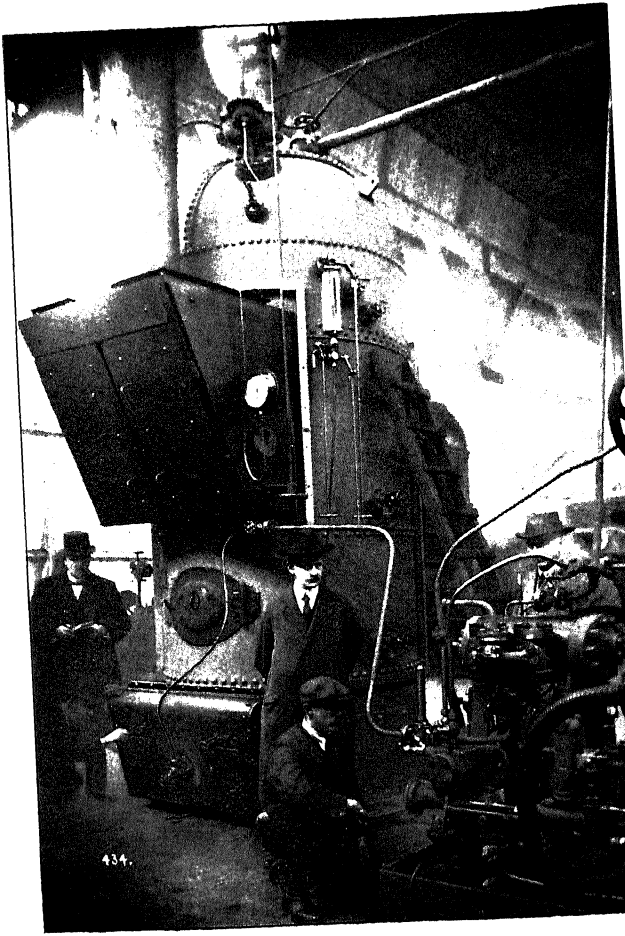


FIGURE 12.

COCHRAN VERTICAL BOILER UNDERGOING A STEAMING
THE MAKERS' WORKS; SHEWING KERMODE'S PATENT
JET OIL-FIRING APPARATUS IN ACTION.

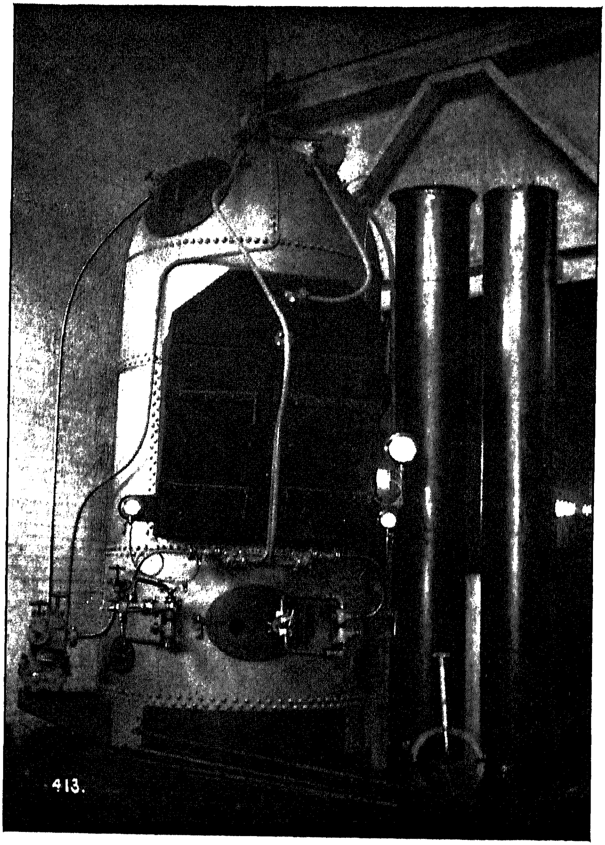


FIGURE 13.

COCHRAN VERTICAL BOILER FITTED FOR BURNING EITHER COAL OR OIL. KERMODE'S PATENT STEAM JET SYSTEM FIRING THROUGH FIREHOLE.

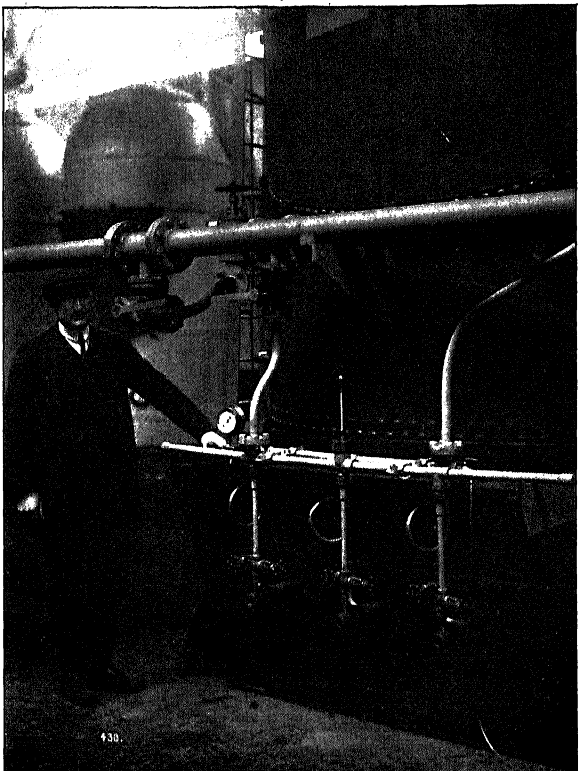


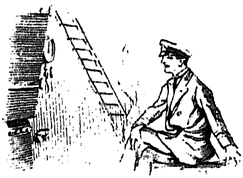
FIGURE 14.

STEAM JET BURNERS FITTED TO COCHRAN VERTICAL BOILER OF LARGE LAND INSTALLATION.

illustration. It consists of the fuel heater, fuel pump, duplex strainers, thermometer, &c.; all mounted on a common base-plate. On board ship, two such installations are carried as a safeguard against breakdown.

Fig. 13 shews a Kermode steam jet burner. This burner is shewn firing through the firehole, and can be swivelled out of the way to enable the boiler to be fired with coal. A Superheater is fitted in the smokebox to superheat the steam for the burners. There is also a direct steam supply pipe for use in emergencies.

Fig. 14 is a close view of a set of steam jet burners applied to some large boilers installed in Persia.



SECTION 6.

Storage Tanks.

In the mercantile marine, oil fuel is generally stored in the double bottom of the ship, and in the fore and aft peak tanks. In tank steamers, side bunkers may be fitted.

All oil storage tanks must be properly isolated by coffer-dams. These are narrow spaces between bulkheads, containing water. They are situated at each end of the storage tanks.

Storage tanks contain the following fittings: air pipe, sounding pipe, steaming pipe, heating coils, test cocks, and filling pipe.

The air pipe is a 3 or 4 inch pipe, open to the atmosphere on deck, and reaching down inside the tank to within a few inches of the highest oil level. This pipe must terminate in a swan-neck, and the open end must be covered with wire gauze. This gauze screen prevents a naked flame from striking back up the pipe, and so causing an explosion inside the tank.

A screw-down stop valve is fitted immediately below the swan-neck, so that the contents of the tank can be completely shut off from the atmosphere in the unlikely event of an internal fire. This would help to quell the flames by cutting off the supply of oxygen.

An air pipe is required to allow of free escape of gas when the oil expands or contracts under the influence of temperature changes. It also permits the free escape of air when the tank is being filled.

Storage tanks must never be completely filled unless they are provided with expansion trunks. Sufficient space must always be left to permit free expansion of the oil under thermal influences. About 6 per cent. of the total capacity of the tank should be sufficient for this purpose.

The sounding pipe is about 2 inches in diameter, and extends right down the tank to within three or four inches of the bottom. It is used for determining the oil level in the tank by means of a steel sounding rod attached to a steel tape.

All storage tanks should be sounded at regular intervals (say daily), and a record kept of the soundings.

This will enable the oil consumption to be checked, and any abnormal consumption, due perhaps to leakage, is detected at once before any damage ensues.

Sounding pipes must be closed after use by screwed plugs to prevent ingress of water.

A useful check upon the oil level in the tanks is given when a combined vacuum and pressure gauge is fitted to the suction pipe.

A pressure reading on this gauge indicates that there is a good head of oil in the tank, whilst a vacuum reading indicates that the level is getting low. It is an easy matter to calibrate this gauge so as to give an approximate indication of the actual oil level.

Steaming pipes, supplied by quick-action relief valves, are part of the fire-fighting arrangements. They should extend about half-way down the tank, and terminate in oblong nozzles.

In the event of fire these nozzles will inject a flat, widely-spread jet of steam into the flames.

Steaming pipes should be supplied from a separate pipe-line, having a master valve on the boiler top.

It is of the utmost importance that all fire service fittings be maintained in thorough working order, and any negligence in this matter should be very severely dealt with.

Steam-heating coils are used for thinning the oil in cold weather, so as to produce a ready flow to the fuel pump.

The temperature of fuel oil must not fall below 50 degrees Fah.

On the other hand, the oil must not be heated to the temperature at which inflammable vapour is given off, on account of fire hazard; and because trouble will be experienced with the pump due to vapour accumulations in the suction pipes.

One square foot of heating surface, with high-pressure steam, will heat from 10 to 20 gallons of fuel oil from 50 to 260 degrees Fah. in an hour—the quantity of oil which can be dealt with depending upon the density.

The heating coils in the tanks should have from ½ to 1½ square feet of heating surface for every ton of oil stored. These coils are usually of grid formation, and are made of 2 inches diameter seamless steel tube. They are placed on the bottom of the tank, and should be arranged to lie close to the suction pipes and strum boxes.

With this arrangement the chief function of these coils is greatly assisted, viz., to reduce the viscosity of the oil so that it will flow freely to the fuel pump.

All heating coils must be perfectly steam-tight, to prevent water formation in the tanks due to steam condensation.

One of the greatest troubles in connection with an oil-burning plant is when water finds its way into tanks and pipes.

If water reaches the burners, the fires will be extinguished at once, and the only remedy is to shut down and get rid of the water.

It is important, then, to test the storage tanks at frequent intervals for water. This is done by using the test cocks which are fitted near the bottom of the tank.

The test cocks are placed half-way between the high and low suction valves, *i.e.*, about 9 inches above the bottom of the tank.

The difference in specific gravity between water and oil causes the water to sink to the bottom of the tank. Its presence is then easily detected by running a quantity of fluid out through the test cock.

If regular tests are made, the water level need never reach the height of the high-suction valve.

A hand-pump is provided for pumping out water.

Two suction valves are fitted to the tank—a high-suction placed about 18 inches above the bottom, and a low-suction placed as close to the bottom as possible.

The high-suction will always be used under ordinary circumstances, the only occasions requiring the use of the low-suction being when the oil level is low, or when the tank must be drained for cleaning or repair.

When the low-suction is in use constant watch must be kept to detect water.

Extension spindles must be fitted to all main suction valves to enable them to be closed from the deck in cases of emergency.

Sometimes a variable suction outlet is obtained by

using either a telescopic suction pipe or a length of flexible hose suspended by suitable lifting tackle.

This device is very useful where excessive water formation is anticipated, since it enables the fuel pump to draw from almost any level.

Too much importance cannot be attached to this matter of water formation. The trouble usually originates in leakage from the heating coils, and, naturally, is more serious in cold weather, when a large amount of artificial heating is required.

On the Canadian Lakes, for example, oil fuel was a comparative failure owing to the large amount of heating which was necessary in winter-time. This produced such excessive accumulations of water that it was quite impossible to keep the fires alight.

All suction pipes should have ample area to allow unrestricted flow to the pumps. In practice the diameter of these pipes ranges from 1¼ inches for plants developing 600 I.H.P. to 4 inches for plants developing about 10,000 I.H.P.

The velocity of the oil in the suction pipes varies from 20 to 55 feet per minute.

The risk of fire is considerably reduced by storing sufficient oil for each working period in small cylindrical tanks called settling tanks. This isolates the main bulk of the oil from the engine and boiler rooms.

These tanks also function as settling tanks, in which water and other impurities may settle to the bottom and be easily removed.

Oil is pumped from the main storage tanks into the settling tanks by a transfer pump. There should be at least two settling tanks fitted, so that the impurities may

have time to settle in one tank whilst the burners are fed from the other.

Each tank must be capable of holding enough oil to last one watch of four hours.

Settling tanks must be fitted with air vent pipes, and a float index gear for indicating the oil level. Glass gauges are not permissible owing to the possibility of breakage, and to the liability for the glass to become discoloured by the oil.

Steam-heating coils are fitted, having 2 sq. ft. of heating surface for every ton of oil stored in the tank.

By heating the oil the separation of water is materially assisted. This is due to an increase in the difference between the densities of water and oil with temperature. This effect is greatest at a temperature of about 180 degrees Fah. In practice, the temperature of oil in the settling tanks lies between 120 and 130 degrees Fah.

All impurities which collect in the settling tanks must be drained away by each watch before refilling the tanks.

Storage tanks must be strong enough to withstand oil pressure when only partially filled, and in a seaway.

They are tested by a head of water reaching to a point at least 12 feet above the load line of the vessel, or above the highest point of the tank, whichever is the greater.

If oil is stored in double bottoms, under hold spaces, an air space of at least 2 inches must be left between the tank top and the ceiling.

No woodwork must be used in the stokehold.

Heat insulation must be provided where storage tanks are situated near boilers.

Special precautions must be taken to ensure that the pumping system for all oil compartments is absolutely independent of those for other parts of the vessel.

In cases where it is desirable to make provision for using the oil storage tanks as water ballast tanks but where the possibility of such provision being actually utilised is so remote as to render the expense of providing independent fuel oil and water pipe lines unwarranted, the following device may be introduced :—

A loose piece of piping is carried, which can be used to connect the oil fuel pipe line to the water ballast pipe line. This eliminates the possibility of mixing water and oil through the opening of the wrong valve or through valve leakage. Before water can be pumped the connection between the fuel oil pipe line and the fuel oil transfer pump must be broken and blanked off, and the loose pipe inserted to connect up the fuel oil pipe line to the water ballast pump.

In cases where the double bottom may be used either for oil storage or for water ballast, it is necessary to provide suitable means for preventing the fuel pumps from drawing water, and the ballast pump from drawing oil. This end is usually gained by having a loose connecting pipe which can be coupled to the oil main or to the water main as occasion requires.

Oil leaking from the storage tanks must be collected by trays, and led to a separate part of the bilges, separated from the main bilge by a deep coaming on the tank top. The oil is removed from this point by a connection to the bilge pump.

Before commencing any work upon the interior of an oil storage tank, it must be thoroughly steamed out and air ventilated to remove all traces of vapour. When work is to be done in the tank involving the use of fires, the air must be tested by a chemist.

SECTION 7.

Suction Strainers—Cold Filters—Hot Filters.

In passing from the storage tanks to the fuel pump, the oil is strained through the suction strainers. This removes particles of grit and other solid impurities which may be held in suspension in the oil. Neglect to provide suitable means for the removal of these impurities would result in choked suction pipes and fuel pump passages.

The suction strainers are fitted in duplicate, so that there is always a clean set ready for immediate use.

The strainer consists of two perforated sheet-metal baskets enclosed side by side in a cast-iron chest.

Oil enters at one side and flows through each basket in turn.

Suction strainers must be cleaned at regular intervals, say once or twice a week, depending upon the grade of oil in use.

The task of cleaning the baskets is considerably lightened by washing them in paraffin oil. This loosens the grit from the perforations of the basket, and enables the cleaning process to be properly finished by sponging and brushing.

In replacing the baskets care must be taken to re-make the cover joints perfectly oil-tight.

To test for oil-tightness, the inlet and outlet valves to the cleaned strainers are opened, and those on the working strainers are closed down. This diverts the oil through the cleaned set, and any leakage is easily detected by oil oozing out under the cover.

The cover joints are generally of the groove and spigot

type. Thin asbestos board is used as the jointing material. Sometimes a great deal of difficulty is experienced in making a sound joint with this type of packing, and it usually requires frequent renewal when the strainers are opened up at frequent intervals for cleaning. This trouble can be overcome by packing the groove with soft packing such as is used for pump spindles.

The suction strainer plates or baskets are usually about $\frac{1}{4}$-inch thick, and are perforated with $\frac{3}{8}$-inch holes, $\frac{1}{2}$-inch pitch.

The areas through the holes should be from 3 to 4 times the area of the suction pipe. This permits of an unrestricted flow when the strainer is partially choked, and eliminates the necessity for frequent cleaning.

Cold Filters and Hot Filters.

These are usually identical in design. They are placed on the delivery side of the fuel pump so that the oil is forced through them under a pressure of from 35 to 135 lbs. per sq. inch.

A much stouter design is therefore required than was the case with the suction strainers.

Frequent cases occur of the collapse of the baskets in these filters due to insufficient strength or improper support.

The baskets of oil filters are of wire gauze to give a sufficiently fine mesh for the complete removal of all particles of solid matter. It is important, therefore, that adequate support be given to keep the baskets in shape under the pressure of the oil.

Fig. 15 shews a very neat design of fuel oil filter. There are two baskets, one within the other. The oil first passes

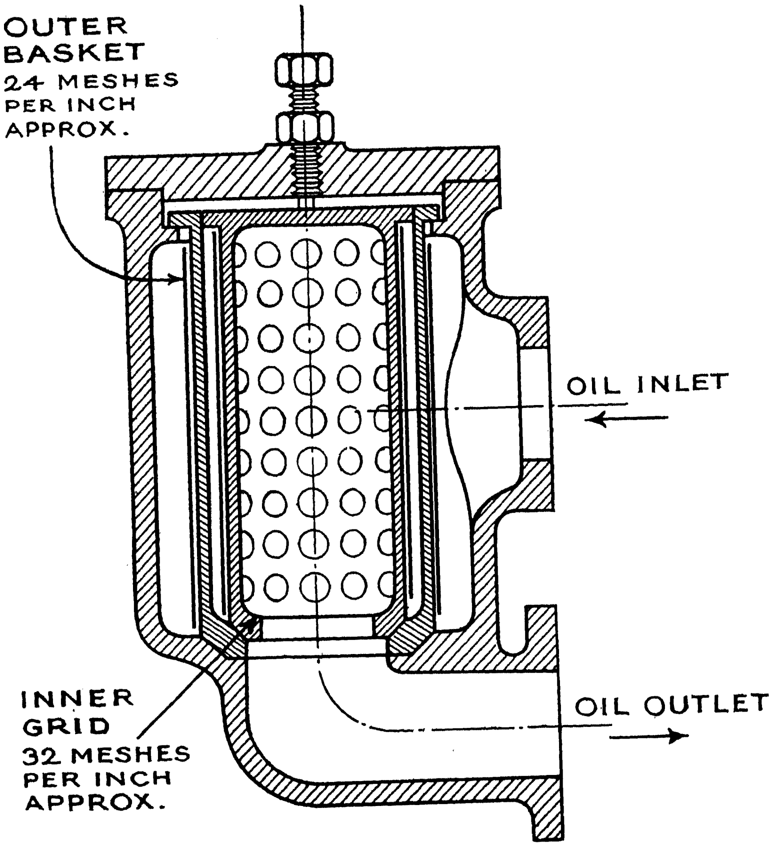


FIGURE 15.

OIL FUEL FILTER.

through the outer basket, which is of slightly coarser mesh than the inner basket. The steel wire gauze forming the filtering medium is supported upon thin steel cylinders perforated with $\frac{1}{4}$ to $\frac{1}{2}$ inch diameter holes.

The oil is discharged through the bottom of the baskets, and it is necessary to make the mitre joints of the cages a reasonably good fit.

The filters are fitted in duplicate to allow of one set being closed down for cleaning.

A good device for detecting when a set of filters is becoming choked is illustrated in Fig. 5.

Two pressure gauges are fitted, one on the inlet side of the filters, and one on the outlet side.

If the filters are clean, both gauges will register the same pressure; but if the passage is becoming choked, the gauge on the inlet side will shew a higher pressure than the gauge on the outlet side.

As soon as the pressure on the outlet side has fallen appreciably, the clean stand-by filters should be brought into operation, and the choked baskets removed for cleaning.

A dirty set of filters not only interferes with the proper functioning of the burners, but also throws extra strain upon the piping of the system.

The cold filters are placed between the fuel pump and the heater. They remove particles of solid matter which may have escaped the suction strainer, or have been picked up in passing through the fuel pump.

The hot filters are placed between the heater and the burners, and remove any particles of solid carbon which may have been formed in the oil during passage through the heater.

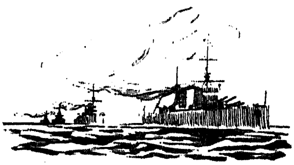
The hot filters are usually larger than the cold filters, to allow for the greater space occupied by hot oil.

The filtering medium consists of fine-mesh steel wire gauze, say 32-mesh for the outer baskets, and 24-mesh for the inner baskets.

The cages which support the wire gauze are about $\frac{1}{4}$-inch thick, and are perforated with a large number of $\frac{1}{2}$-inch diameter holes.

The area of the holes through the outer cage should be from 10 to 12 times the area of the delivery pipe. This will give a corresponding ratio for the inner cage of from 7 to 9.

With the area of the holes in the cages fixed by the above ratios, no difficulty should be experienced in obtaining an area through the wire gauze of the inner grid of from 3 to 4 times the area of the delivery pipe. By leaving this margin of area the filters may become partially choked without seriously hindering the free flow of oil. This will increase the time intervals between cleaning. The larger ratios quoted above are for the hot filters.



SECTION 8.

Fuel Heater.

An efficient fuel heater is fitted in pressure systems of burning oil. The function of this heater is to raise the temperature of the oil to the proper degree for correct combustion in the furnaces. We will see later how very important this matter of oil temperature is in relation to the efficient management of the plant.

The heater is placed between the fuel pump and the burners, and is generally fitted in duplicate to provide for emergencies.

The oil flows through the heater under pressure, so that a certain stoutness of design is required, not only to withstand the oil pressure, but also to guard against oil leakage.

The heater follows closely the design of a small surface condenser—that is to say, it consists of a large number of straight tubes enclosed between tube plates inside a steel shell.

The heating medium is steam, which flows round the outside of the tubes.

Straight tubes are preferable to spiral coils, owing to the tendency which a coil possesses to straighten out under internal pressure. This is due to flat parts on the walls of the coil, and in practice it is never possible to produce perfectly round coils on a commercial basis.

Retarders are fitted in all the tubes, consisting of twisted steel wire. The retarders delay the passage of oil through the tubes, and this brings the oil into more intimate contact with the walls of the tubes.

No brass or gun-metal parts should be present in the heater, because of the liability for corrosion to set in.

The tubes are of seamless steel, expanded into steel tube plates.

By expanding the ends of the tubes into the tube plates, the difficult problem of preventing oil or steam leakage is satisfactorily solved.

It is highly important that no leakage of oil into the steam space, nor of steam into the oil space, shall take place. Either event might have serious consequences. The water might reach the burners and quench the fires, and the oil might find its way into the boilers.

Oil leakage into the steam space is detected by fitting a special observation tank, or alternatively, an open funnel, into which the steam drain from the heater discharges on its way to the boiler feed tank.

Fig. 16 shews a typical heater. It will be noticed that the type illustrated is a double flow heater, *i.e.*, the oil flows first along the top set of tubes and then along the bottom set. This tends to increase the efficiency of the heater by making the oil passage more tortuous and by increasing the velocity of flow.

The temperature of the oil is regulated partly by the amount of opening given to the steam inlet valve, but principally by the setting of the drain valve.

A water-collecting chamber is fitted below the drain valve, and the temperature should be regulated by the amount of water in this chamber. This can be seen at all times in the gauge glass shewn in Fig. 17. A usual setting for the drain is to run with the water-collecting chamber half filled.

In all types of heating apparatus, it should be remembered, the highest efficiency is obtained when the drain valve is just open enough to maintain the required temperature. This is a matter which is often lost sight of in practice.

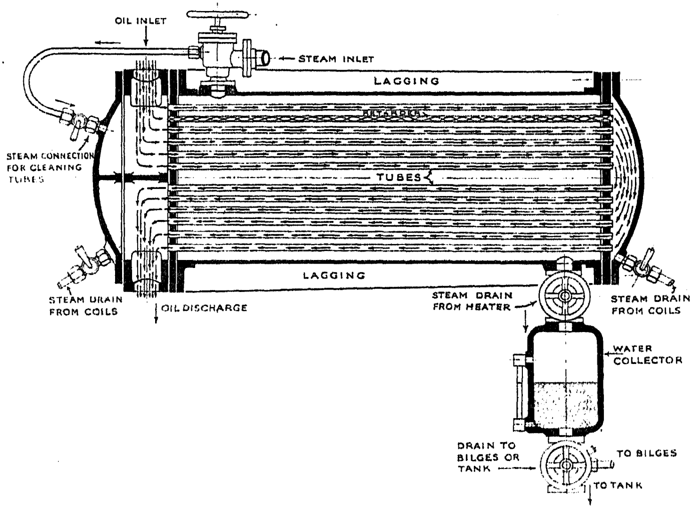


FIGURE 16.

OIL FUEL HEATER.

A small steaming pipe is fitted to the oil side of the heater, *i.e.*, to the inside of the tubes. This enables the tubes to be cleaned, as occasion requires, by steaming out.

It is important to keep the tubes clean, since choked passages entail increased oil pressure to overcome the additional resistance to flow, and there may also be a drop in temperature.

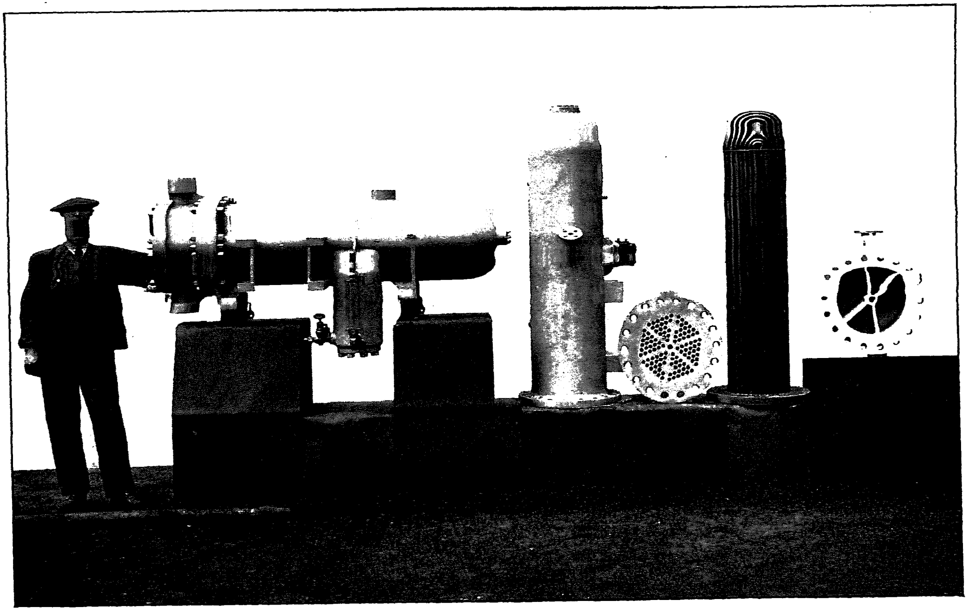


Figure 17. Oil Heater as fitted in the Wallsend-Howden System. On left hand a Complete Heater, on right hand Unassembled Parts.

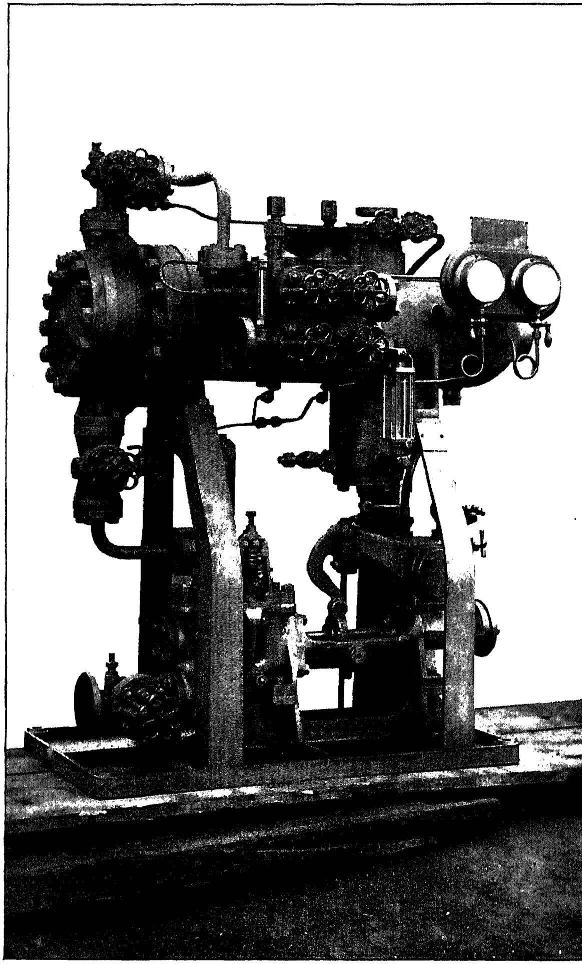


FIGURE 18.

COMPLETE UNIT OF PUMPING AND HEATING PLANT AS FITTED IN THE WALLSEND-HOWDEN SYSTEM.

Figs. 17 and 18 shew the heater, etc., supplied with the Wallsend-Howden system of burning liquid fuel.

In Fig. 17 the various details of the heater are seen on the right of the illustration. These consist of the oil inlet and outlet chamber, containing diaphragms which direct the flow of oil through the tubes; the tubes themselves, which form a U-shaped coil and are supported in a single main tube plate; the tube plate; and the heater body.

The heater is shewn assembled on the left of the illustration. Note the oil inlet and outlet branches, the feet for bolting the heater in place, and the water-collecting chamber fitted with drain valve and gauge glass.

Fig. 18 shews the Wallsend-Howden oil-burning apparatus (pressure system), consisting of fuel heater, fuel pump, duplex strainers fitted in duplicate, pressure gauges and thermometer, all mounted on a common base-plate provided with a save-all drip tray.

Note the two pressure gauges. One is connected to the delivery side of the filters, and one to the inlet side. Choking of the filters can be detected by the readings on these gauges, which should be identical if the passage is clear.

Note also the water-collecting chamber just below the heater, and the steaming pipe connected to the oil inlet pipe to the heater.

SECTION 9.

Fuel Pumps.

There are two main types of fuel pump on the market—the duplex pump fitted with an ordinary "D" slide valve, and the Weir pump fitted with the shuttle valve motion, which is a specialty of this firm.

Both these types are double-acting, and both may be obtained in either vertical or horizontal designs. The small pressure pump which supplies oil to the burners is generally horizontal, because it is easy to accommodate, and can be arranged to be bolted to a bulkhead with one cylinder on either side of the partition.

The fuel oil transfer pump is larger than the pressure pump, and is generally of the vertical type.

Fig. 19 shews a pressure pump, and Fig. 20 a transfer pump.

Pressure Pumps.

Before much attention had been devoted to a study of the conditions under which fuel oil pumps must operate, it was loosely stated by well-known authorities who ought to have known better, that any pump capable of lifting water would be equally capable of lifting oil.

This might be true in the case of some of the lighter oils, like benzine or paraffin, but it did not require much experimental work to prove the fallacy of the statement when heavy fuel oil was in question.

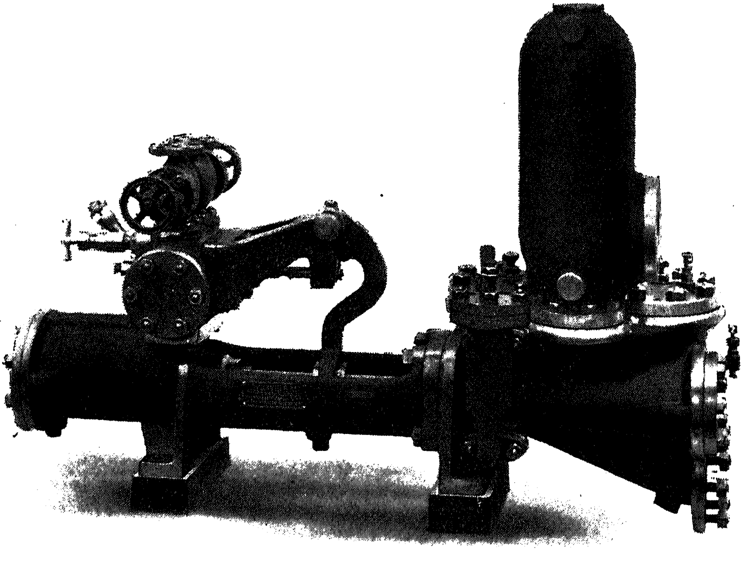


Figure 19.

Oil Fuel Pressure Pump.

(G. & J. Weir, Ltd.)

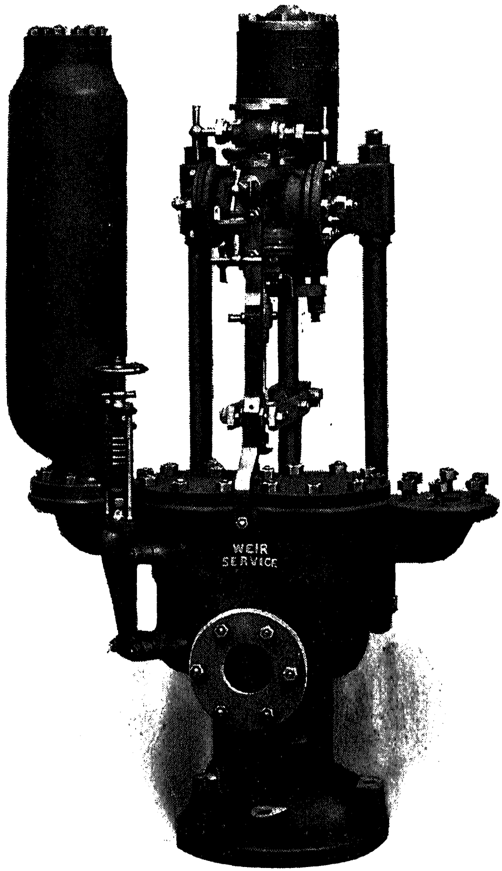


FIGURE 20.

OIL FUEL TRANSFER PUMP.

(G. & J. WEIR, LTD.)

The principal factors governing the design of a pump suitable for dealing with this class of oil are : —

The pump must be capable of handling a very viscous fluid—*i.e.*, the passages must be of ample area, to afford the least possible resistance to the passage of the oil. The areas through suction and delivery valves must also be large, for similar reasons.

The pump must be able to deal with any accumulations of gas which may be present when first starting up.

The pump must be able to handle oil at a temperature of not less than 80 degrees Fah.

No brass or gun-metal should be used in constructing the pump, because of the liability for acid action to take place. This is especially important when oils rich in sulphur are to be dealt with. The usual materials of construction are—steam and pump cylinders, framing, and pistons of cast-iron ; valve operating gear of steel ; valves of steel ; valve seats and valve guards of cast-iron.

The pump must be simple in design, and afford free access to all vital parts.

Further desirable features are, a positive valve motion, and economy in steam consumption.

The possession of the first item means that it is impossible for the pump to stick, *i.e.*, there is always certainty of action.

It is also important that the suction pipes be of ample area to allow free flow of oil to the pump. All pipe connections must be as direct as possible, and special care must be taken to avoid any restrictions of area, or the introduction of sharp bends and loops. Restrictions of area are avoided by fitting sluice valves in the suction pipe system.

Air leakage must be prevented at all costs, since this is one of the most likely factors to interfere with the proper functioning of the pump. The pipe system must contain no blind corners which may develop air locks, and systematic inspection is recommended for leakage at joints.

The Weir pressure pump, already illustrated, is one of the pumps which have given very good results in practice.

It also possesses an unique feature which has met with a great deal of success as applied to boiler feed pumps, viz., the Weir shuttle valve gear. We propose to give a brief description of this gear :—

The valve motion is positive, *i.e.*, the pump will always start directly steam is turned on. This result is acheived by fitting two slide valves inside the valve casing. Both valves are simple slide valves—the main valve controls the steam distribution to the working cylinder, whilst the auxiliary valve distributes steam to operate the main valve.

The main valve is half-round, and works on a semicircular face inside the steam chest. The ends of this valve are formed into pistons, which fit into two cylindrical castings accommodated at each end of the valve casing.

The auxiliary valve is flat, and works on a flat face cut on the back of the main valve. Ports in this face communicate with the cylindrical castings in which the ends of the main valve slide.

The cycle of movements is as follows :—When the piston is at the bottom of its stroke, the main valve is at one end of its travel, and is admitting the full steam supply to the bottom of the piston. The piston, therefore, begins its upward travel, and the steam port remains full open until, at half stroke, the valve gear begins to move the auxiliary valve. At about three-quarters stroke, the

auxiliary valve has been moved far enough to cut off the supply of steam to the bottom of the cylinder completely. The rest of the stroke is then completed by the expansion of the steam in the cylinder.

Just as the piston reaches the top of its stroke, the auxiliary valve admits steam to one end of the main valve and throws it right over to the other extremity of its travel. This admits steam to the top of the piston, and the same cycle is repeated on the down stroke. The main valve is brought quietly to rest by a cushion of exhaust steam.

From the brief description, the following three facts may be gathered :—

1. The valve gear is positive in action—*i.e.*, the main valve which distributes steam to work the piston can only be at rest when it is at full travel.
2. The valve gear provides for expansive working, thus reducing steam consumption.
3. The work to be done by the valve levers is very light, since they have merely to move the small auxiliary valve on the back of the main valve.

Fuel pumps are fitted in duplicate so that one pump can be overhauled or repaired whilst the other is in service.

It is good practice to overhaul the pumps at regular intervals, and on some vessels the custom is to use one pump on the outward passage, and change over for the return.

Prevention is always better than cure. By keeping both pumps in proper condition the possibility of a complete stoppage due to pump failure is practically eliminated.

An air vessel is fitted on the delivery side of the pump

to secure an even flow of oil. This ensures steady combustion, and prevents pulsation.

The air vessel is charged through a small snifting valve.

A spring-loaded relief valve is fitted to protect the system from an excessive rise in pressure.

The discharge from this valve is lead back to the suction side of the pump through a return pipe.

Should the pump at any time shew a tendency to race, whilst maintaining a high vacuum on the gauge, the trouble will probably be traced to a choked suction strainer.

A small hand-pump is provided for pumping water from the storage tanks, and for circulating the oil when starting up from cold.

With the smaller sizes of pressure pump, the design can be arranged to allow of the pump being operated by hand as well as by steam.

Fig. 21 shews the relative sizes of an oil-fuel pump and a feed-water pump. It must not be thought that the fuel pump is a large and ponderous machine. On the contrary, it is the smallest independent power pump on board the ship.

About 1 lb. of oil is consumed per I.H.P. per hour; and assuming a steam consumption of 15 lbs. per I.H.P. per hour, this means that the feed pumps must have 15 times the capacity of the fuel pump if they run at the same speed.

Consider a 3000 I.H.P. engine, having a fuel consumption of 1 lb. per I.H.P. per hour. The total oil consumption would be about 50 lbs. per minute. Taking the specific gravity of oil at 0·9, this gives a consumption of roughly 1 cubic foot per minute.

A pump, $2\frac{1}{2}$-inch bore by 6-inch stroke, running at 30

r.p.m. (60 strokes per minute), would be capable of supplying all the oil required.

The table on page 68 gives the pump capacities recommended by Messrs Weir.

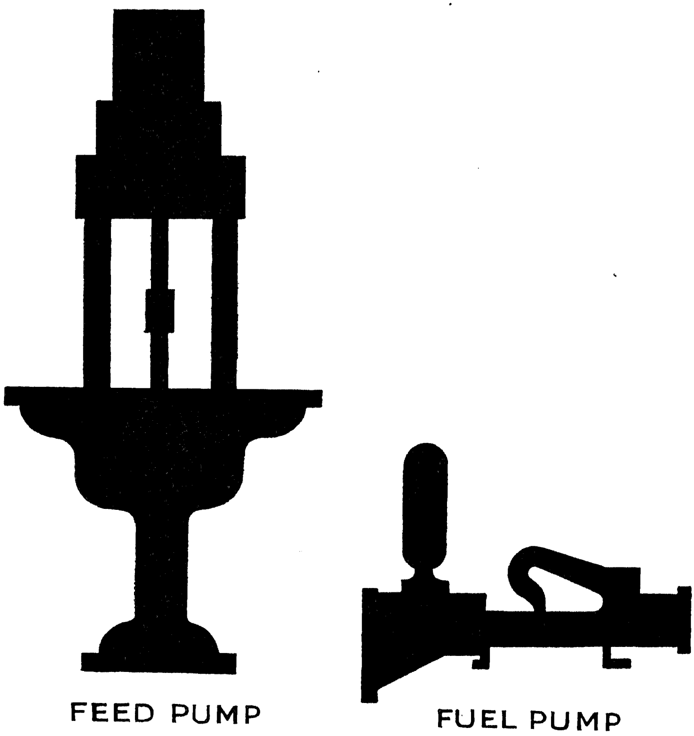


FIGURE 21.

DIAGRAM SHEWING THE RELATIVE SIZES OF AN OIL FUEL PRESSURE PUMP AND A BOILER FEED PUMP.

TABLE I.

FUEL PUMP CAPACITY (WEIR).

Size of Pump.			Capacity.				Size of Pipes.				I.H.P. of Plant served by Pump.	
			Good Navy Oil. S.G.=0·90.		Heavy Mexican Fuel Oil. S.G.=0·97.		Steam.		Oil.			
Oil Cylinder Dia.	Steam Cylinder Dia.	Stroke.	Double Strokes per Min.	Gallons per Hour.	Double Strokes per Min.	Gallons per Hour.	Inlet.	Exhaust.	Suction.	Discharge		
2″	3″	4″	30	74	15	34	½″	½″	1¼″	¾″	600	800
2½″	3½″	5″	30	210	15	98	½″	½″	1½″	1″	1750	850
3″	4½″	6″	30	450	15	210	½″	½″	2″	1½″	3750	1750
3½″	5¼″	7″	30	740	15	350	¾″	¾″	2½″	1¾″	6250	3000
4″	6″	8″	30	1120	15	520	¾″	¾″	3½″	2½″	9500	4500
5″	7¼″	7½″	27	1480	15	780	¾″	1″	3½″	2½″	12,500	6500
5″	7¼″	10″	25	1870	15	1080	¾″	1″	4″	3″	15,750	9000

Volumetric Efficiency of Pump = 75 to 85%.
The Table is based on a Temperature of 80° F., and a Fuel Consumption of 1·01 lbs. per I.H.P. per Hour.
Per cent. of Total Power Absorbed by Pressure Pump 0·025% to 0·05%.
Do. Do. with Steam Atomization 5%.
Do. Do. with Air Atomization 2½%.
Velocity of Oil in Suction Pipes 20 to 55 feet/min.
Velocity of Oil in Delivery Pipes 40 to 110 feet/min.

The table is based on oil at a temperature of 80 degrees Fah., and a volumetric efficiency for the pump of about 80 to 90 per cent.

The power has been calculated on the basis of 1·01 lb. of oil per I.H.P. per hour.

The velocity of the oil in the suction pipes varies from 20 to 55 feet per minute, according to the density of the oil.

The velocity in the delivery pipes varies from 40 to 110 feet per minute.

The proportion of the total power required to drive the pump and heater is $1\frac{1}{4}\%$.

Compare this with the corresponding figures for the other systems of atomization :—

Steam atomization, 5 per cent.
Air atomization, $2\frac{1}{4}$ per cent.

These figures shew that steam atomization consumes four to eight times as much power as pressure atomization, whilst air atomization consumes about twice as much.

The actual evaporative capacity of the various systems of atomization, assuming fuel oil having a calorific value of 19,320 B.T.U. per lb., are—

Air atomization	...	15·6 to 16·6 lbs. evaporation.
		78 to 83 per cent. efficiency.
Steam atomization	...	13·6 to 14·8 lbs. evaporation.
		68 to 74 per cent. efficiency.
Pressure atomization	...	14 to 15 lbs. evaporation.
		70 to 75 per cent. efficiency.

The evaporation is from and at 212 degrees Fah.

If allowance is made for the power absorbed in working the atomizer these figures become—

Air atomization	...	15·2 to 16·1 lbs. evaporation.
		76 to 80 per cent. efficiency.
Steam atomization	...	13 to 14 lbs. evaporation.
		65 to 70 per cent. efficiency.
Pressure atomization	...	14 to 15 lbs. evaporation.
		70 to 75 per cent. efficiency.

Note.—The theoretical evaporative capacity of 1 lb. of oil, calorific value 19,320, is 20 lbs. from and at 212 degrees Fah.

SECTION 10.

Distribution Boxes and Burners.

Distribution Boxes.

The heated oil passes from the hot filters, under pressure, to distribution boxes on the boiler fronts.

These distribute oil to the burners, and consist of solid steel forgings, containing one screw-down valve for each burner.

This permits of any burner being shut off independently.

The valves are case-hardened, so that the seats can be ground in at any time to give perfect oil-tightness.

It is highly important that these valves be maintained oil-tight.

Though questionable practice, it is permissible to screw down the valves with the aid of a wheel spanner, if by so doing freedom from oil leakage can be assured.

If oil leakage at the burners escapes detection two things will usually occur—

Smoke will at once make its appearance, and this in itself should be sufficient indication that there is something wrong. There will also be an accumulation of oil in front of the burner. This oil will eventually drip down into the ashpit, where it will ignite. The result will be a cracked ashpit door, followed by a pool of blazing oil on the stokehold plates.

As a further precaution against this form of leakage, it is usually arranged, where several boilers are served by a common delivery pipe, that each boiler can be shut off from the main supply pipe independently.

A thermometer pocket is provided near the distribution box to check the oil temperature just before it enters the burner, *i.e.*, just before atomization.

Oil is piped from the distribution boxes to the burners by $\frac{3}{8}$-inch or $\frac{1}{2}$-inch copper tube.

Large-size union nuts should be fitted to these pipes, because of the frequency with which they are dismantled.

When dismantling a burner for cleaning both unions—*i.e.*, the union at the distribution box end and the union at the burner end of the pipe—should be disconnected.

The common practice of unscrewing the burner union only, and then bending the supply pipe clear, should not be tolerated. It always ends in broken pipes.

The union nuts are preferably made of steel, since this reduces the liability of threads stripping at awkward moments.

Occasionally, armoured flexible hose is used to convey oil from the distribution boxes to the burners. This arrangement, though more expensive at the start, effectively prevents the expense and nuisance of broken pipes.

Burners.

Much ingenuity and untold wealth have been lavished upon the design of pressure atomizers.

The principal features which differentiate one type of burner from another are in the size, number, and disposition of the various oil passages within the body of the burner.

The aims which the designer of an efficient burner has in view are :—

1. To produce an oil spray which will burn like gas.
2. To make it possible for all grades of oil to be handled.
3. To obtain 1 and 2 with as low an oil pressure as possible.
4. To obtain 1 and 2 without introducing an excessive oil temperature.
5. To combine all these factors into a simple and robust instrument.

The importance of the first item is manifest when it is mentioned that a poor oil spray may leave deposits of liquid oil on furnace plates. There may also be isolated jets of flame, which will act like a blow-lamp upon portions of the furnace plates.

In the early days, these contingencies were guarded against by lining the exposed parts of the furnace with firebrick. Brickwork baffles were also necessary, in some types of furnace, to deflect the flame at critical points.

It is significant of the advance which has been made, that the modern marine boiler furnace requires very little or no brickwork lining. The assumption to be inferred is that modern atomizers function so well that the oil is completely consumed in the air space of the furnace, though it must also be admitted that the size of the modern furnace may have a certain influence.

The second item has led to a certain complication of design, but the results obtained in most cases well repay this additional work.

With the third and fourth items we enter that section of the subject which is perhaps one of the most difficult to handle.

Oil can be sprayed by a modern atomizer at as low a pressure as 20 lbs. per sq. inch, but the spray will not be good. The minimum pressure range for proper atomization is from 35 to 150 lbs. per sq. inch, depending upon the quality of the oil. These figures are not at all excessive. The objection to high oil pressures is found in the greater difficulty which is experienced in preventing oil leakages.

The question of temperature largely depends upon the grade of oil used. The minimum temperature at which

oil will ignite depends upon the flash-point. The flash-point must not be less than 175 degrees Fah., because of fire hazard, and this gives at once the limit to which temperature can be lowered by using low-gravity oils.

The oil temperature should never exceed 275° Fah., or trouble will be experienced due to "cracking," with consequent stoppage of the burners through carbonization.

When handling very heavy oils it is always preferable to increase the oil pressure to obtain proper atomization, rather than raise the temperature above 275° Fah.

The oil temperature in an average pressure system ranges from 90 degrees Fah. (stokehold temperature) to 190 degrees Fah.

The two last items, simplicity and robust design, have been met very successfully. This is evident when it is remembered that one fireman, without much previous experience of oil-burning installations, can manage twelve fires quite comfortably.

The output of a burner is defined as the number of lbs. of Texas oil which it passes per hour at a standard temperature of 200 degrees Fah. and a pressure of 150 lbs. per sq. inch.

The amount of oil passed must be adjusted to suit the boiler power, bearing in mind that each cubic foot of air space in the furnace is only capable of dealing with about 6 lbs. of oil per hour.

As a general rule, each burner can pass from 250 to 500 lbs. of oil per hour. Thus, for a 3000 I.H.P. engine consuming 3000 lbs. of oil per hour there could be from 6 to 12 burners, depending upon the size of orifice fitted.

The amount of oil passing the burners must be regulated to suit variations in steam consumption.

This adjustment should be made without exerting any material influence upon the efficiency of the whole system —a point which will be explained later.

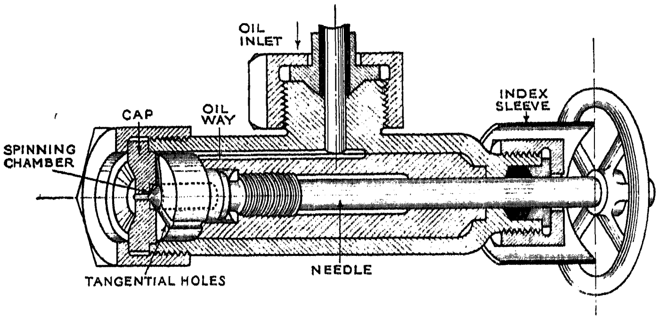


FIGURE 22.

KERMODE PRESSURE JET BURNER.

Fig. 22 shews the Kermode pressure burner. The oil passes along channels cut horizontally in the burner body to a series of tangential grooves cut in a steel disc near to the exit orifice.

In passing along these tangential grooves a rapid whirling motion is given to the oil. The rotary motion thus acquired is kept up in a small chamber just behind the exit orifice. This chamber is therefore called the spinning chamber. From the spinning chamber the oil passes through the exit orifice and emerges into the furnace in the form of a fine spray.

The size of the exit orifice is controlled by a screw-down needle valve operated by a graduated hand-wheel. A

clearance of 1/500 of an inch must be allowed between the point of this needle and the inner edge of the exit orifice.

This protects the sharp edge of the hole from damage. Two principal types of Kermode burner are manufactured —the single orifice type and the duplex type. The single orifice type has one exit orifice, and 1, 2, or 3 tangential

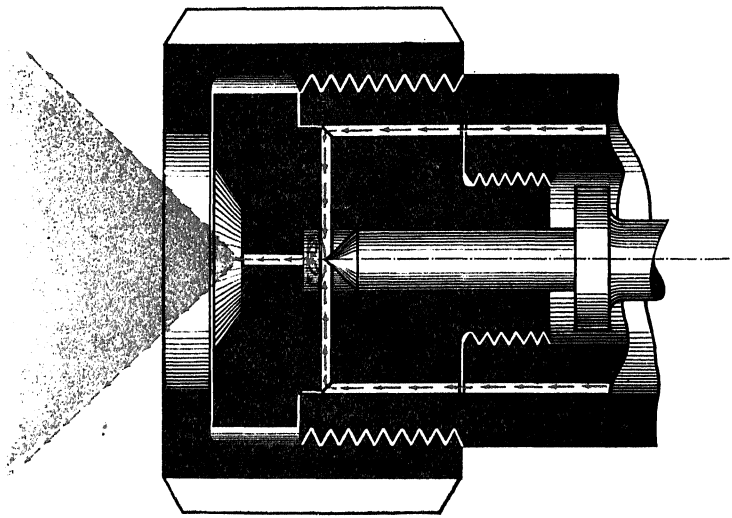


FIGURE 23.
KERMODE PRESSURE BURNER NOZZLE.

holes. The duplex type has two exit orifices, and 9 tangential holes. An increase in the number of tangential holes increases the angle of divergence of the resulting spray.

Fig. 23 shews an enlarged end view of the Kermode burner. The way in which the oil is whirled before exit is clearly indicated.

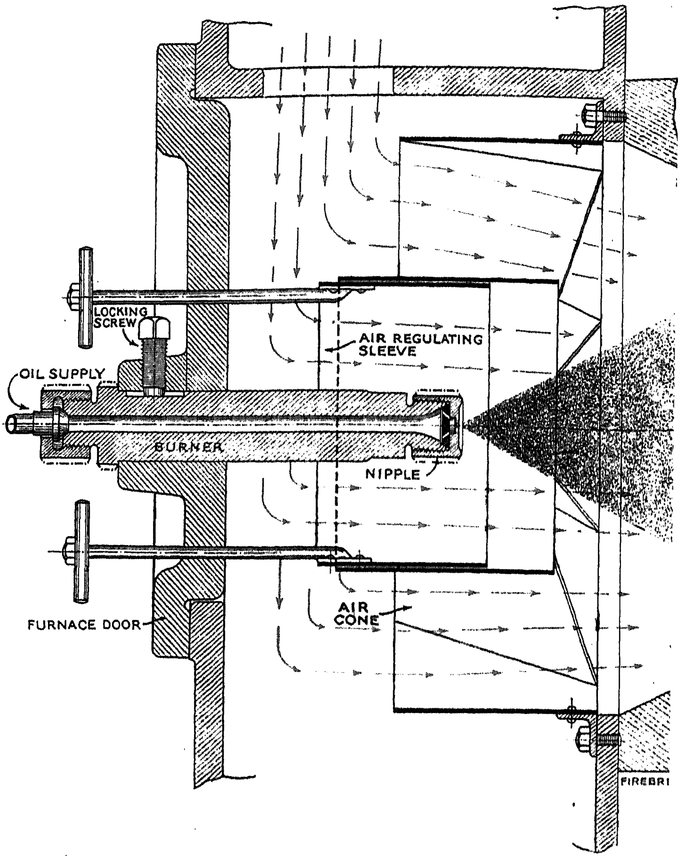


FIGURE 24.

DIAGRAMMATIC ARRANGEMENT OF A PRESSURE BURNER WORKING UNDER FORCED DRAUGHT.

(Wallsend-Howden Patent System.)

The Wallsend-Howden pressure burner is shewn in Fig. 24. It is extremely simple in design, and can therefore be relied upon to withstand hard wear and a lot of rough usage.

Fig. 25 shews an enlarged end view of the burner. It is at this point that atomization is accomplished. The oil passes through two tangential holes into a circular chamber behind the exit orifice. A rapid whirling motion

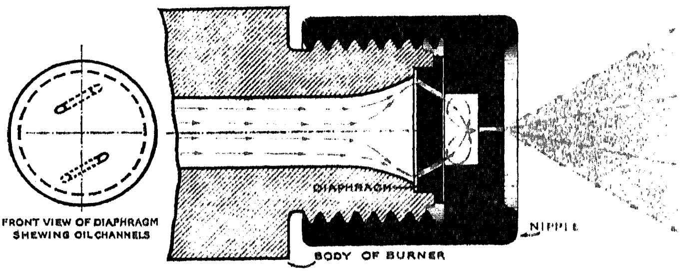


FIGURE 25.
WALLSEND-HOWDEN PRESSURE BURNER NOZZLE.
(Old Pattern.)

is thus imparted to the oil, which then enters the furnace as a finely divided spray.

The design is simplified by omitting the adjusting needle. Regulation is obtained by carrying a carefully graded set of nipples and diaphragms. These are numbered in pairs, and the capacity of the burner can be adjusted with very little trouble by unscrewing the existing nipple, removing the diaphragm, and inserting a new nipple and diaphragm of the required size.

The burner is secured in place by a small set screw. This must be securely tightened into the groove cut to

accommodate it in the burner body. A loose burner might be thrust out of its socket.

Fig. 26 shews the latest type of Wallsend-Howden pressure jet burner. This method of mounting the burner is a distinct improvement, since it enables the burner to be withdrawn in the minimum of time, and without disconnecting the oil supply pipe.

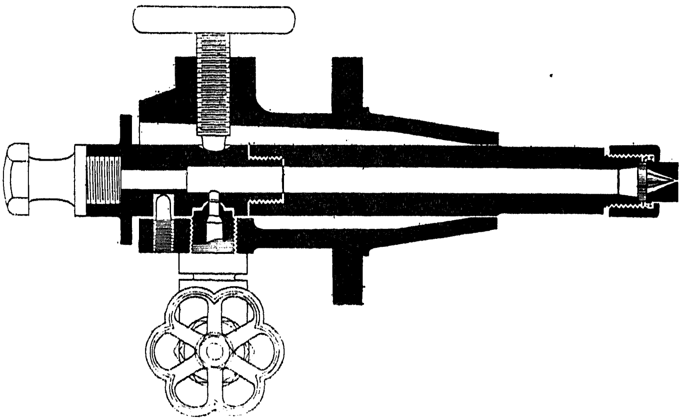


FIGURE 26

WALLSEND-HOWDEN PRESSURE BURNER.
(New Pattern.)

The burner is carried in a tubular holder, which bolts on to the furnace front.

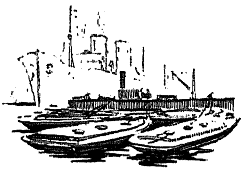
By slackening back the retaining screw, one is able to lift the burner off the oil inlet pipe union, and then pull it bodily out of the furnace.

The valve carried beneath the burner must not be used for regulating the oil pressure at the burner. This

adjustment is made at the steam valve of the oil pressure pump.

The burner valve is used for isolating burners which require attention, and replaces the distribution valve boxes previously mentioned.

In the case of boilers having several furnaces, it is preferable to have a distribution valve box, instead of valves on the burners themselves, in order that any fire-door can be opened without the necessity of shutting off the oil supply to all the furnaces of the boiler.



SECTION 11.

Draught—Raising Steam.

Draught.

Fig. 27 shews a pressure burner arranged for natural draught. A circular steel plate supports the burner, which projects through the air cone.

The air cone is from 12 to 15 inches in diameter, and is bolted to the front of the furnace. The air is deflected

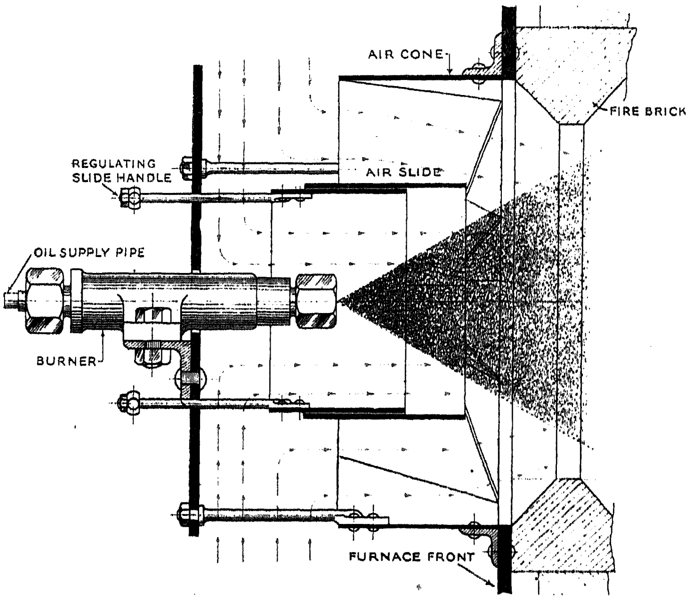


FIGURE 27.

DIAGRAMMATIC ARRANGEMENT OF A PRESSURE BURNER WORKING UNDER NATURAL DRAUGHT

(Wallsend-Howden Patent System.)

by the front plate into the air cone. The centre portion of this cone consists of a cylinder surrounding the burner. A sliding sleeve fits loosely inside, and can be moved to and fro.

The annular space between the inner cylinder and the outer casing of the air cone is divided into a number of segments by thin plates which wind spirally round the circumference of the inner cylinder. These partitions impart a spiral motion to the incoming air, which assists atomization. Another useful purpose which these partitions serve is to prevent direct radiation of heat from the interior of the furnace. This is accomplished by making each partition overlap its neighbours, so that at no point in the annular space between the inner and outer cylinders of the air cone is the flame inside the furnace directly exposed to the stokehold.

A ring of firebrick surrounds the air cone at the side nearer the furnace. The outer casing is cooled by the passage of air.

The draught is regulated by loose flaps hinged to the front plate. These flaps are not shewn in the illustration.

The circular sleeve which slides inside the air cone controls the supply of air to the centre of the burner. If this shutter is pulled right back so that it lies against the front plate, all the air must pass into the furnace through the spiral passages of the air cone proper. As the loose sleeve is pushed further and further forward, more and more air is admitted to the centre of the burner until a point is reached at which the flame will be seen to contain specks of incandescent carbon floating in it.

Correct adjustment is obtained when these specks are just on the point of appearing.

It should also be noted that the larger the amount of air admitted to the centre of the burner, the greater will be the impetus given to the spray. Thus the flame will be projected further along the furnace.

With proper regulation of the air supply, the oil spray should ignite at a distance of about 4 ins. from the burner tip. This prevents over-heating of the burner.

Fig. 24 shews a pressure burner arranged on Howden's system of forced draught. Here the air cone is enclosed in an air box, supplied by fans. The adjustment of the central sliding shutter is made exactly as already described.

Fig. 28 shews the complete furnace as arranged for burning oil under this system of forced draught.

There are three air control levers. An air check valve (C), which nominally controls the supply of air to the top of the furnace; two lower check valves (D), which control the supply of air to the bottom of the furnace; and the central air shutter (B), which regulates the air supply to the centre of the burner.

Other fittings on the furnace front are—an access hole for inserting the torch when lighting up, mica windows for inspection purposes, and a small hole in the ashpit door for inserting a U-tube to ascertain the ashpit air pressure.

With forced draught the proper amount of air is best determined by experience, but in general the air pressure will be less than with coal, because with solid fuel the greater proportion of the pressure is spent in forcing air through thick fuel beds.

About 2 inches of fan pressure (0·072 lbs. per sq. inch) will be found to meet most normal conditions of working.

This will give an ashpit pressure of about $1\frac{1}{2}$ inches of water (0·054 lbs. per sq. inch).

The air is heated by passing it round tubes in the smokebox through which the products of còmbustion pass on their way to the funnel. The air is heated to a temperature of about 200 degrees Fah.

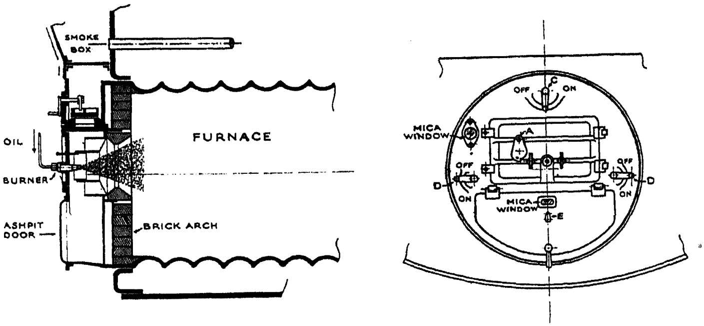


FIGURE 28.

FURNACE ARRANGEMENT FOR BURNING OIL UNDER FORCED DRAUGHT.
(Wallsend-Howden Patent System.)

In an induced draught system, thè stokehold is closed to the atmosphere, and can only be entered through an arrangement of doors forming an air lock.

Air is pumped into the stokehold direct by fans capable of maintaining a steady air pressure of the required amount.

The furnace fittings are very similar to those used when burning oil under natural draught.

The advantage of induced draught is found principally in the simplification of furnace fittings, and in the absence of any need for air trunks between the fans and the boilers. This last item is particularly prominent when large boiler

powers are to be installed. About 18 lbs. of air, or 200 cubic feet are required to burn 1 lb. of oil in practice.

Raising Steam.

It is wise practice to equip all boilers burning liquid fuel with hydrokineters.* This instrument is used for circulating the water in the boiler by means of an auxiliary steam jet supplied from the donkey boiler or from shore.

The hydrokineters should be allowed to operate for at least nine hours before lighting any fires. This insures that the boilers are thoroughly warmed through, a very necessary precaution with liquid fuel, since steam-raising develops rapidly once the fires have been lighted.

The boilers should not carry a full charge of water when the hydrokineters are started, since there is a rise in water level of about 6 inches due to steam condensation.

For an hour or so previous to lighting up, the oil must be circulated through the heater in order to raise its temperature to a sufficient degree for ignition to take place.

The whole oil-burning system is first flooded with oil by opening the main suction valve on the bunkers and drawing a sufficient quantity of fuel into the system by working the fuel pump slowly.

Care must be taken to see that all valves on the burner distribution boxes are tightly closed.

When all the pipes, &c., in the system are properly flooded the pump is stopped, and the bunker isolating valve is closed. The oil may then be circulated round the closed pipe line shewn in Fig. 29.

This circulation should be carried out with the fuel pump working as slowly as possible.

* A Hydrokineter is not necessary in the Cochran Boiler (see page 89).

A temperature of not less than 120 degrees Fah. is generally required to ensure ignition in the furnaces.

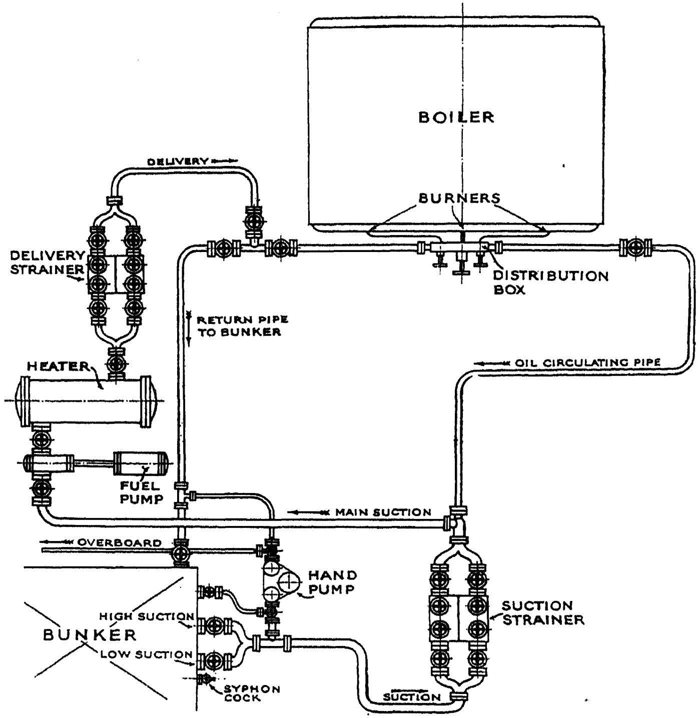


FIGURE 29.

PLAN OF A PRESSURE JET OIL-BURNING INSTALLATION.
(Shewing Oil Circulating Pipe.)

The procedure outlined above is only possible when there is an auxiliary source of steam available. In the

absence of this convenience, special fittings must be resorted to.

The oil may be circulated by means of a hand-pump, whilst Fig. 30 shews the means used for heating the oil.

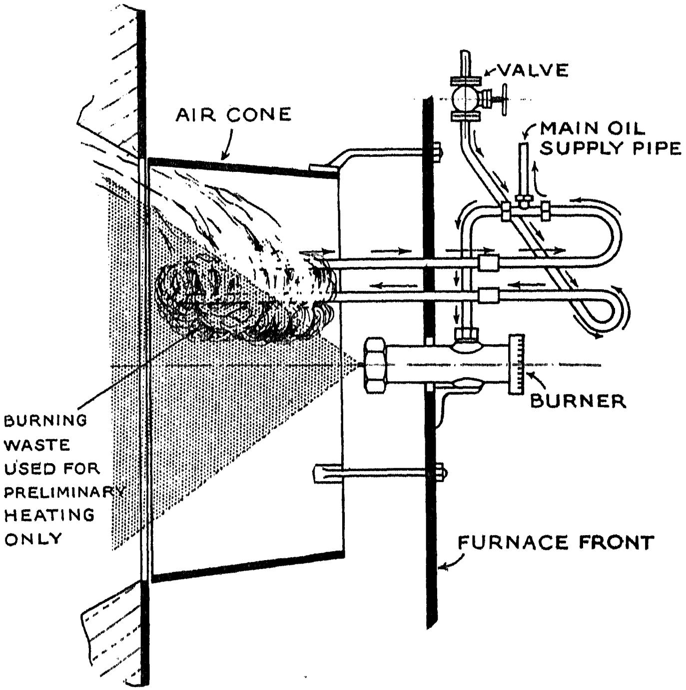


FIGURE 30.

PRESSURE BURNER WITH U-TUBE ATTACHED FOR STARTING UP.

A steel U-tube is attached to the oil supply pipe near the burner. Oil is circulated through this tube by the hand-pump; and is heated, initially, by burning cotton

waste soaked in oil, which is wrapped round the loop of the tube.

Part of the hot oil is sprayed on to the burning waste by the burner, and the remainder circulates round the system.

After a few minutes' preliminary heating in this way, the action becomes automatic—*i.e.*, the oil spray from the burner ignites, and the spent waste drops off the U-tube.

The circulating oil is then heated solely by the burner spray, and, when steam is available for the heater and fuel pumps, the U-tube is withdrawn and the working burner inserted—(Fig. 30A).

A pressure of from 50 to 60 lbs. per sq. inch must be maintained by the hand-pump to keep the oil in constant and steady circulation.

Another method of preliminary heating is to fit a small auxiliary heater burning naphtha.

When the temperature of the oil has risen sufficiently, the next step in forced draught installations is to start up the fans. This must be done very slowly at first.

Here, again, trouble is experienced if no auxiliary steam is available to work the fan engines. The difficulty is overcome by propping open the ashpit doors sufficiently to give a certain amount of "natural" draught.

Having attended to the question of draught, we may then proceed to light the fires.

In order to prolong the period of steam raising, it is desirable to use a small burner orifice.

Thus, in burners of the Kermode type the needle valve should be screwed down, whilst in burners of the Wallsend-Howden type a small-sized nipple and diaphragm should be substituted for the regular working size. Thus, if a

No. 19 or a No. 20 size was used for normal steaming, a No. 12 or a No. 14 size should be used when raising steam.

The remaining precautions required are—to work the

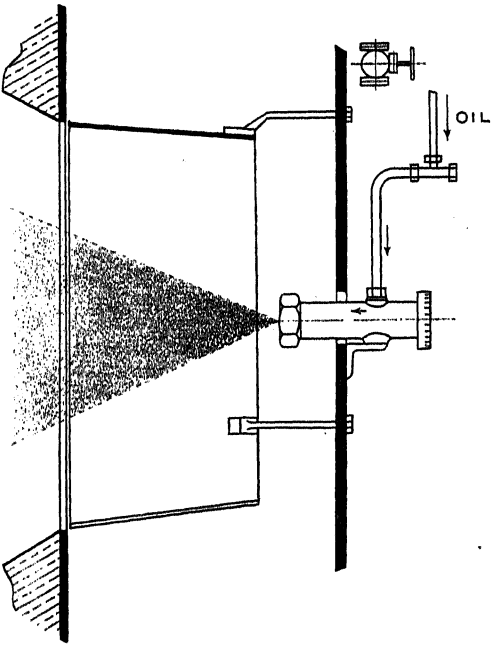


FIGURE 30A.
U-TUBE REMOVED.

fuel pump as slowly as possible, and to light only one fire in each boiler until a reasonable head of steam shews on the gauges.

In no case should the full head of steam be raised in less than five hours.

The last remarks apply with special force to Scotch boilers. In the case of water-tube boilers, the capacity for forcing is well known. Cases could be cited in which steam was raised in about 20 minutes in a water-tube boiler burning liquid fuel, though three hours is considered the normal period for these boilers.

With regard to the Cochran Boiler, $1\frac{1}{2}$ to 2 hours may be taken as safe practice, as there is no "dead," or cold water, *all* the water being in circulation.

When starting to light a fire, the air regulator admitting air to the top of the furnace (C in Fig. 28) must be opened, and the lower regulators (D in Fig. 28) must be closed.

Neglect of this precaution often leads to serious blow-backs into the stokehold when the torch is applied to the spray. This is due to too much air being admitted at once.

The spray is ignited by a torch made by binding cotton waste soaked in paraffin on to the end of a steel rod.

Once the spray is properly ignited, all air checks may be opened. The fuel pressure should then be kept as low as possible, consistent with smokeless combustion.

When a fire is shut off for cleaning, care must be taken to shut all air check valves. This prevents a rush of cold air across the furnace.

The valve on the oil supply pipe to the burners must not be opened until the torch is in position ready to ignite the spray; whilst accumulations of oil vapour should be blown out of the furnaces by opening the air intakes for a few minutes immediately before lighting the fires.

SECTION 12.

Efficiency.

There are five factors to be considered relative to the all-important question of efficiency.

They are all more or less interconnected.

They are :—

DRAUGHT.	OIL PRESSURE.
OIL TEMPERATURE.	SIZE OF BURNER.

CONDITION OF FIRES.

The principal criterion of efficiency is the funnel. The best results are invariably obtained when there is but the faintest haze of smoke visible at the funnel.

Dealing with each factor in turn :—

Draught.

An insufficient air supply produces black smoke at the funnel, and for highest efficiency there should be just sufficient air to eliminate this.

Too much air produces white smoke. This is due to the cooling effect which the excess air produces in the furnace. This allows a large amount of oil vapour to escape unconsumed up the funnel.

The setting of the air slide controlling the air supply to the centre of the burner also requires proper regulation. This has already been described in detail.

As a general rule, the fan pressure will vary from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches of water. The exact amount required depends upon the number of fires in operation—*i.e.*, upon the evaporation required at the moment.

Oil Temperature.

This factor has a very important bearing upon the efficiency of the plant.

Too high a temperature produces white smoke, whilst too low a temperature produces black smoke.

The aim of the Engineer-in-charge should be to burn the oil at as low a temperature as possible, consistent with smokeless combustion.

Excessive temperature also introduces a tendency for heavy carbon deposits to form in the furnaces.

The correct working temperature varies greatly with the grade of oil in use. It depends chiefly upon the flash-point of the oil, and may be as low as 90 degrees Fah. (stokehold temperature).

An average figure is 140 degrees Fah., though it may reach as high as 275 degrees Fah. with certain grades of heavy Mexican fuel.

A point to note in connection with this matter of oil temperature is, that any decrease of temperature necessitates a corresponding decrease in oil pressure to maintain the original head of steam.

A rather striking instance of this fact is afforded by the experience of a certain ship during the war.

The vessel was under shell fire from a U-boat, and it became urgently necessary for the boilers to be forced to their utmost capacity. But the engine-room staff quickly discovered that the steam pressure could not be sustained above normal for any length of time, even with the highest safe pressure of oil which the fuel pump could deliver.

The Chief Engineer decided to try lowering the temperature. Two things happened as a result of this. The fires smoked heavily, due to the abnormal relationship

between pressure and temperature ; and secondly, an extra head of steam was easily obtained, which enabled the ship to show a clean pair of heels to the submarine. This last item was all that mattered.

This curious relationship between oil temperature and oil pressure is probably due to the readiness with which hot oil gives off vapour.

Hence, as the oil temperature increases, vapour is given off more and more rapidly, until a point is reached when nothing but oil vapour or gas enters the furnace.

When this point is reached vapour is formed so rapidly that a large proportion escapes unconsumed up the funnel.

A certain amount of solid carbon is also deposited in the furnace.

The limit is reached when the escaping vapour is visible at the funnel in the form of white smoke.

The escape of so much unconsumed oil results in an increased demand on the fuel pump, which now has to supply sufficient oil to evaporate the water in the boiler, and also to allow for a certain amount escaping unconsumed.

High temperatures may also become a source of danger, since the instantaneous liberation of large volumes of gas may produce explosive mixtures in the furnace. The result will be a severe blow-back into the stokehold, and "pulsation."

Pulsation may be due to excessive oil pressure or to excessive draught, as well as to excessive temperature.

It gives rise to violent vibrations of the fittings on the furnace fronts, and these movements generally extend to the smokebox, uptake, and lower funnel plates if they are not checked in time.

It is hardly necessary to add that such a state of affairs is dangerous, and must be remedied at once.

Oil Pressure.

The correct oil pressure for proper atomization depends upon the grade of oil in use. There is, however, a certain narrow range of pressure within which the oil must be sprayed to give maximum efficiency.

The size of burner, number of fires, and oil temperature all exert a material influence upon the oil pressure.

The aim should be to burn the oil at as low a pressure as possible, consistent with smokeless combustion and the steaming conditions of the moment. This will put the least possible strain upon the pipe-lines and fittings, and reduce any tendency for leaks to develop.

Smoke is produced by too low or too high a pressure. In both cases black smoke is produced.

Smoke may be eliminated by altering the fuel pressure, but it must be remembered that this may entail an alteration in either the temperature or the size of the burner orifice in order to maintain the original head of steam.

If the temperature adjustment is correct for a given sample of oil, any adjustment to eliminate smoke must be made by altering the pressure.

The full number of fires should always be in operation. The practice of shutting down fires to decrease the evaporation is bad. It may result in oil leakage into the furnace.

The best practice is to make an adjustment like this by altering the size of burner.

Oil will spray at a pressure of 20 lbs. per sq. inch, but with poor atomization. The normal pressure range is from 35 to 150 lbs. per sq. inch. In practice it is usual to aim at an average pressure of 60 lbs. per sq. inch. This leaves a certain margin above and below for running adjustments.

Size of Burner.

The burner orifice must be large enough to give steady steaming with normal oil pressures and temperatures, and with the full number of fires in operation.

Too large an orifice will tend to increase consumption, because one or other of the factors governing efficiency will not be in correct adjustment.

Too small an orifice will be subject to the annoyance and labour of cleaning burners at very frequent intervals.

Experience alone will tell the Engineer-in-charge which burner orifice is best suited to the steaming requirements of his plant.

State of Fires.

The state of the fires is perhaps one of the most prolific causes of bad combustion.

It is also one of the easiest to remedy, since it involves nothing more than a few minutes' hard work with the rake and slice.

But, perhaps, the necessity for hard work is the principal reason why the fires are so frequently neglected.

No carbon should be allowed to collect in the furnaces, especially directly in front of the burners. Whenever solid carbon is detected in the furnaces it must be broken up into a form suitable for combustion. The cause of this carbon formation should also be investigated, and the remedy applied. It will usually be the result of too high an oil temperature.

Regular inspection of all the furnaces must be made, and the proper attendance to this duty should not be left to the discretion of the fireman. Cases could be cited in which lack of vigilance resulted in a solid wall of carbon forming

right across the front of the burner from side to side of the furnace. This resulted in a cracked ashpit door.

Another cause of dirty fires is found in dirty burners. One cannot expect to produce a spotless ceiling with a dirty whitewash brush.

The burners are liable to become coated with carbon, and the small passages in nipples and diaphragms are also liable to be partially choked with grit. It is good practice, therefore, to withdraw all burners at regular intervals for cleaning.

Thus, on a twelve-fire set, a practice should be made of cleaning four burners each watch. The complete set of burners would then be given attention twice every 24 hours.

Spare burners are carried to replace those withdrawn for cleaning.

The cleaning process should be thoroughly carried out by stripping the burner completely.

Paraffin oil is used for loosening scale from the external and internal surfaces of the burner body, whilst the small oil passages may be cleared of grit by probing them with a piece of copper wire.

Summary.

The rules governing the proper management of an oil-burning plant are very simple, and follow a logical sequence.

The funnel is the indicator of good combustion.

White smoke indicates that there is either too much draught or that the oil temperature is too high. The remedy is to reduce either of these factors until black smoke is on the point of making its appearance.

White Smoke is Inexcusable.

Black smoke, with normal oil pressure, indicates usually a deficient air supply. If an adjustment of the draught does not supply the remedy, re-adjust the oil pressure.

If the smoke still persists, inspect the fires.

They will be found to be dirty, and a few minutes' work with the rake and slice will put matters right.

It must at all times be remembered that absolute cleanliness and freedom from oil leakage are essentials, not only from the efficiency point of view, but also from considerations of safety.

No leakage should be overlooked, even if it entails half-an-hour's work at the bottom of an oil storage tank caulking seams.

Frequent inspection should be made for leakage by a responsible member of the staff, such as the Engineer on watch. Faults should be immediately notified, and the necessary steps taken to put matters in order.

Hot water is useful for cleaning oil from metal surfaces, and a plentiful supply of dry sand must be kept handy for dealing with fire.

The following ten rules form a useful guide for the proper maintenance of an oil-fired plant :—

Ten Rules.

1. Avoid smoke—this indicates waste.

2. Correct the air supply—excess air cools the furnaces, and produces white smoke—deficient air produces black smoke.

3. Correct the oil temperature—white smoke indicates too high a temperature and heavy carbon deposits in the

furnaces — black smoke may indicate too low a temperature.

4. Correct the oil pressure—black smoke may indicate either too high or too low a pressure.
5. Clean the fires and burners at regular intervals.
6. Keep all standby filters, pumps, and heaters clean and ready for immediate service.
7. Eliminate fire hazard by adopting proper precautionary measures—inspect regularly for oil leakage—prevent oil accumulations—keep a supply of sand at hand for eventualities.
8. Prevent accumulations of water in storage tanks—water won't burn.
9. Adjust the burners to suit evaporation by altering the size of orifice—don't shut off one or two fires.
10. Steam and ventilate tanks thoroughly before attempting internal repairs.

Part II.—Oil Fuel on Land.

SECTION 1.

Oil as an Agent for the Production of Steam on Land.

The principal aim of this section is to make a direct appeal to all who are concerned with the economical production of steam on land.

Recognition of the many advantages which oil fuel offers for *Marine* purposes is now quite general; but this cannot be said of *Land* practice.

To-day, the handicap of a prohibitive price is so far removed as to render the comparison of oil with coal a matter demanding rather more than superficial attention. It is no longer sufficient to compare the costs per ton of the two fuels and accept this as a true criterion of relative economy.

Both the fuel and labour markets have altered to such an extent in recent years, that a true comparison can only be effected by careful consideration of many factors other than price. Points to be decided relatively include —Cost of fuel, Supply of fuel, Heating value, Labour, Maintenance, Control over fires, and Storage.

Cost and Supply.

Cost and *Supply* are considered to be vital factors in deciding the issue, and so will be discussed first.

During 1920 the prices of oil at various American ports were :—Tacumate, 34/- per ton; Galveston, 45/- per ton; Port Arthur (Texas), 53/- per ton; and New York, 69/- per ton.

Contemporary figures for the United Kingdom were :—Thames, 200/- to 250/- per ton; Liverpool, 260/- per ton.

These prices indicate that the high cost of fuel oil in Great Britain is directly due to high freights, the result of inadequate transport and storage facilities.

This is the standing grievance associated with our supply of oil, which many authoritative writers on the subject have emphasised from time to time.

In 1908, J. D. Henry, founder of the *Petroleum World*, and author of many valuable works on the subject of oil, wrote :—

" The supply of oil in Oklahoma is limitless, and I write this sentence, a common one in petroleum literature, with a full sense of all that it means when introduced into a serious work of this description. . . . . " This (England) is one of the few countries in which the use of oil for Mercantile Marine and Industrial purposes is more than an ordinary business risk. The chief reasons are patent, and must be frankly acknowledged; they are economic, and, no matter how unwillingly some of us may make the confession, we cannot keep back the truth that the unsolved problems of a prohibitive price, *largely the result of high and fluctuating transport charges*, preclude

the possibility of its early becoming a standard fuel of our national industrial organisation."

The italics are the writer's, and should be read with the following quotation from the *Motorship* for August, 1920 :—

"In an interview with Mr John Purdy, the vice-chairman of the Eagle Oil Transport Co., and Director of the Anglo-Mexican Petroleum Co., Ltd., he expressed the opinion that *the crux of the oil question was transport.* He added the comforting remark that there is plenty of oil in the producing fields, and with adequate transport facilities the supply would soon overtake the demand."

Thus in 1920 the position is much the same as in 1908. Absence of transport facilities and lack of storage have resulted in an highly inflated price for oil fuel in Great Britain.

En passant, another writer on the subject has stated that the Mexican oil production is limited only to the extent of the facilities to take the oil away, and he further estimates that, if necessary, the output could be increased tenfold almost immediately.

Official figures for 1919 gave the potential production of Mexico, in that year, as 84,000,000 tons. However, owing to inadequate storage and transport, the actual output was throttled down to 13,400,000 tons—about 12% of her potential production.

But we may look to the near future for a considerable increase of the present means of transporting and storing oil in bulk. Encouraged by the promise of a permanent demand for oil fuel throughout the world, some of the largest companies are busy extending their facilities for distribution.

Evidence of this activity may be found in the number of new depots which are springing up, and in the large number of tank steamers which are building or on order.

The present instability of the coal market is likely to continue far into the future, and, even under existing circumstances, the price of oil would probably be maintained at a level which just equalised the cost of steam production per pound of each class of fuel.

With the promise of greatly augmented transport and storage facilities, there is every reason to hope that the cost of steam production per pound of oil will ultimately fall considerably below the cost per pound of coal.

With regard to the probable duration of the world's supply of oil, all the published data is not by any means optimistic; but, from the ebb and flow of authoritative opinion, one can at least conclude that there are vast virgin stores of oil scattered throughout the world, only requiring proper exploitation to enable them to contribute their quota in satisfying the ever growing demand.

There appears to be little room for doubt, judging from the opinion held by those who profess to know about such matters, that the undeveloped oil fields of the British Empire alone could supply sufficient oil to make Great Britain independent of foreign supply.

The vital importance of this, in time of war, is too obvious to need much emphasis, and it has long been a puzzle why active Government interest in this matter of Imperial oil resources has not been taken.

In the past Great Britain has relied entirely upon her coal resources; but to-day the position in this trade is so bad, and the prospect of a permanent settlement of all disputes seems so remote, that the development of all

possible sources of fuel supply is a matter of urgent national importance.

Evidence of activity in this direction is found in the oil borings now in progress in various parts of England; whilst perhaps the most notable Colonial enterprise is the development of the oil fields of Trinidad.

The famous pitch lake of Trinidad has long held out attractions to oil-producing companies.

It is a lake, of unknown depth, containing vast quantities of a black, plastic, pitchy substance. Experts are convinced that a huge subterranean reservoir of oil is located under the lake, and a company has been formed to exploit the region.

So far, we have dealt exclusively with the question of the supply of natural mineral oil. We have yet to consider the potential sources of supply of oil manufactured from animal and vegetable matter.

The potential supply of animal and vegetable oils suitable for use as fuel is practically unlimited; whilst we have yet to be convinced that the distillation of mineral fuels, such as coal, would not be the most economical method of burning them.

The extent and probable duration of the world's resources of coal and mineral oil have long been subjects of many dismal and foolish prophecies. The false prophets, in nearly every case, failed to remember that, long before coal was discovered, man had to rely upon animal and vegetable fuels for warmth and for cooking purposes, and that, if necessity arose, he could again fall back upon these ancient sources of supply.

The possibilities in this connection are immense. Intensive and selective cultivation would provide huge

quantities of vegetable oil, whilst oil obtained from the fish in the sea would go a long way towards keeping the commerce of the world in motion.

Even in the very early days of civilisation the heat-giving and illuminating values of oil in one form or another were recognised, and, scattered here and there in the records of antiquity, one may find references to the use of oil for these purposes. About the time of Peter the Great, for example, the sale of oil from Baku was a flourishing business in Persia.

Thus we see that the question of future fuel supplies is not centred round the quantity of natural fuel which lies buried in the earth. We must look above the earth, in the air, and in the sea for vast potential sources of oil supply.

The extent to which we have relied upon coal can be regarded almost as a set-back to progress, inasmuch that it has been the means of delaying important developments in the science of economical fuel utilisation for energy.

There can be no doubt that the dawn of the "Oil Age" has brought man nearer to the true solution of problems connected with the conservation of fuel. Nothing is wholly wasted in nature, and in oil we see the one natural means whereby a balance is struck between fuel expenditure and the replenishment of supplies.

Viewed from this aspect, present-day experience with oil-burning apparatus can be regarded as the preliminary experimental stage for an age when oil will be used for all heating purposes—long after the last particle of coal has vanished from the earth. *So long as the heat of the sun continues, there need be no fear of a cessation of our means for procuring heat energy.*

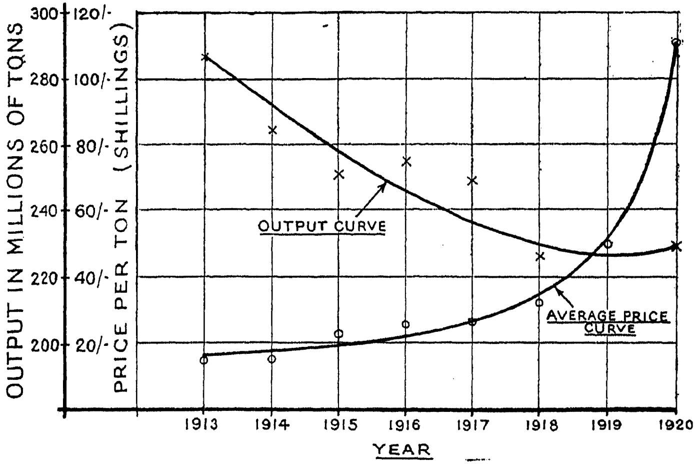


FIGURE 31.

CURVES SHEWING THE OUTPUT AND AVERAGE PRICE OF COAL IN GREAT BRITAIN. (1913 to 1920).

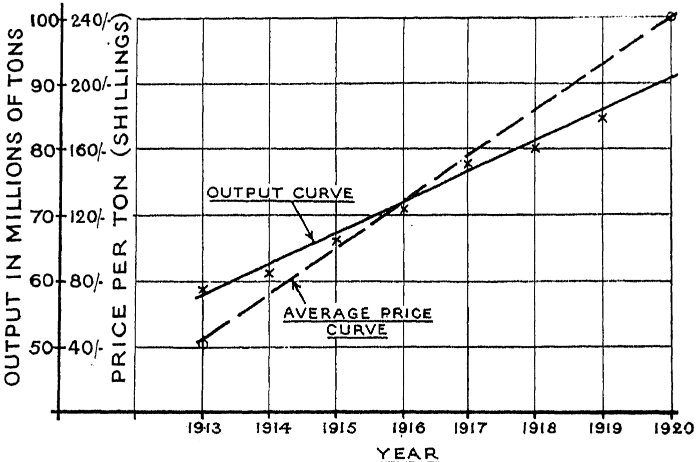


FIGURE 32.

CURVES SHEWING THE WORLD PRODUCTION OF OIL, AND THE AVERAGE PRICE OF OIL IN GREAT BRITAIN. (1913 to 1920).

Up to this point we have been concerned mainly with speculations centred around the remote future. The business man of to-day, however, is more closely concerned with the present cost and availability of fuel. To explain the present position as concisely as possible, a series of curves and tables has been prepared.

Fig. 31 shows graphically the output of coal in Great Britain, and the average cost of coal in Great Britain from 1913 to 1920.

Fig. 32 is a similar diagram for oil fuel.

Tables 2 and 3 show the cost of evaporating 1000 lbs. of water with coal and with oil respectively.

From the curves it is seen that the output of coal in Great Britain has gradually declined since 1913, whilst the average price to the consumer has steadily increased.

The output of oil, on the other hand, over the same period has steadily increased. This has been due to a steadily increasing demand.

The price of oil in Great Britain has also steadily increased, but the proportional increase since 1913 is less than with coal.

In 1910 the price of coal in Great Britain was 12/- per ton, this being about one quarter the price of oil at that time.

To-day, with coal at 60/- per ton and oil at 140/- per ton, the costs are in the proportion of 1 to $2\frac{1}{3}$.

From the tables showing the actual cost of evaporation the following interesting facts are obtained :—

Assume that the average practical evaporation when burning coal is 8 lbs. of water per lb. of coal, and that, when burning oil, this figure is increased to 16 lbs. of water per lb. of oil. Assume also that the cost of coal in 1910

Table 2.

Cost of Fuel for Evaporating 1000 lbs. (100 Gallons) of Water, from and at 212° F.

WITH COAL.

Cost of Coal per Ton.	LBS. OF WATER EVAPORATED PER LB. OF COAL, FROM AND AT 212° F.												
	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
10/-	1/1½	1/-	10¾d	9¾d	9d	8¼d	7¾d	7¼d	6¾d	6½d	6d	5¾d	5½d
20/-	2/2¾	2/-	1/9½	1/7½	1/6	1/4½	1/3¼	1/2¼	1/1½	1/0¾	1/-	11¼d	10¾d
30/-	3/4¼	2/11¾	2/8¼	2/5¼	2/2¾	2/0¾	1/11	1/9½	1/8¼	1/7	1/6	1/5	1/4¼
40/-	4/5½	3/11¾	3/7	3/3	2/11¾	2/9	2/6½	2/4¾	2/3	2/1¼	2/-	1/10¾	1/9½
50/-	5/7	4/11¾	4/5½	4/0¾	3/8¾	3/5¼	3/2¼	2/11¾	2/9½	2/7¾	2/6	2/4¼	2/3
60/-	6/8¼	5/11½	5/4¼	4/10½	4/5½	4/1½	3/9¾	3/7	3/4¼	3/2	2/11¾	2/9¾	2/8¼
70/-	7/9¾	6/11½	6/3	5/8¼	5/2½	4/9¾	4/5½	4/2¼	3/11	3/8¼	3/5¾	3/3½	3/1¾
80/-	8/11	7/11½	7/1¾	6/6	5/11½	5/6	5/1	4/9¼	4/5¾	4/2½	3/11¾	3/9	3/7
90/-	10/0½	8/11¼	8/0½	7/3¾	6/8¼	6/2¼	5/8¾	5/4½	5/0½	4/9	4/5¾	4/2¾	4/0½
100/-	11/1¾	9/11¼	8/11	8/1½	7/5¼	6/10½	6/4¼	5/11½	5/7	5/3¼	4/11¾	4/8½	4/5¾
110/-	12/3¼	10/11¼	9/9¾	8/11¼	8/2¼	7/6¾	7/-	6/6½	6/1¾	5/9½	5/5¾	5/2	4/11¼
120/-	13/4½	11/11	10/8½	9/9	8/11	8/3	7/7½	7/1¾	6/8½	6/3¾	5/11½	5/7¾	5/4½

ALL PRICES ARE GIVEN TO THE NEAREST FARTHING.

Table 3.

Cost of Fuel for Evaporating 1000 lbs. (100 Gallons) of Water, from and at 212° F.

WITH OIL FUEL.

Cost of Fuel per Ton.	LBS. OF WATER EVAPORATED PER LB. OF OIL, FROM AND AT 212° F.														
	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½	17
40/-	1/9½	1/8½	1/7½	1/6¾	1/6	1/5¼	1/4½	1/4	1/3½	1/3	1/2½	1/2	1/1½	1/1	1/0½
60/-	2/8¼	2/6¾	2/5¼	2/4	2/2¾	2/1¾	2/0¾	1/11¾	1/11	1/10¼	1/9½	1/8¾	1/8¼	1/7½	1/7
80/-	3/7	3/5	3/3	3/1¾	2/11¾	2/10½	2/9	2/7¾	2/6¾	2/5¾	2/4¾	2/3¾	2/3	2/2	2/1¼
100/-	4/5¾	4/3	4/0¾	3/10½	3/8½	3/7	3/5¼	3/3¾	3/2¼	3/1	2/11¾	2/10½	2/9½	2/8½	2/7½
120/-	5/4½	5/1¼	4/10½	4/8	4/5½	4/3½	4/1½	3/11¾	3/10	3/8½	3/7	3/5½	3/4	3/3	3/2
140/-	6/3	5/11½	5/8¼	5/5¼	5/2½	5/-	4/9¾	4/7½	4/5¾	4/4	4/2	4/0½	3/11	3/9½	3/8¼
160/-	7/1¾	6/9¾	6/6	6/2½	5/11¼	5/8¾	5/6	5/3½	5/1¼	4/11¼	4/9¼	4/7¼	4/5¾	4/4	4/2½
180/-	8/0½	7/8	7/3¾	6/11¾	6/8¼	6/5¼	6/2	5/11½	5/9	5/6¾	5/4½	5/2¼	5/0½	4/10½	4/8¾
200/-	8/11¼	8/6	8/1¼	7/9	7/5	7/1¾	6/10¼	6/7½	6/4½	6/2	5/11½	5/9	5/7	5/5	5/3
220/-	9/10	9/4¼	8/11	8/6½	8/2	7/10½	7/6½	7/3¼	7/0¼	6/9½	6/6¾	6/4	6/1¾	5/11½	5/9½
240/-	10/8¾	10/2½	9/8¾	9/3¾	8/11	8/7	8/2¾	7/11¼	7/8	7/5	7/2	6/11	6/8½	6/6	6/3¾
260/-	11/7½	11/0¾	10/6½	10/1	9/7¾	9/3½	8/11	8/7	8/3½	8/0¼	7/9	7/5¾	7/3¼	7/0½	6/10

ALL PRICES ARE GIVEN TO THE NEAREST FARTHING.

was 10/- per ton, and of oil 45/- a ton; whilst in 1921 corresponding figures are 60/- a ton for coal, and 140/- a ton for oil.

Then the *cost of fuel* for evaporating 1000 lbs. of water, from and at 212°F., works out thus :—

	1910.	1920.	1921.
Coal	6¾d.	6/1¾.	3/4
Oil	1/3.	6/8½.	3/11

In 1910 the cost of evaporation with oil was more than twice the cost of coal.

To-day the cost with oil, in a similar installation, would be only 7d more than with coal, a difference which is many times refunded by considerations other than price.

Local conditions will, of course, considerably influence the relative costs of evaporation. In certain districts in England it is possible to obtain coal at 35/- per ton. Under these circumstances, oil at 140/- per ton could not possibly compete unless there were factors other than price to be considered.

In concluding these remarks on cost and supply, the following summary of the points discussed is given :—

1. The high cost of oil fuel in England is largely the result of inadequate transport and storage.

2. The supply of mineral oil is limited, but it might be that no exact information concerning the extent of the world's oil deposits is yet available.

3. Oil is the fuel of the future; animal and vegetable oils will undoubtedly be in use long after the coal resources have become exhausted.

4. The cost of fuel per lb. of steam raised is, at present, practically the same for oil as for coal.

5. The small difference in fuel cost in favour of coal is easily balanced by the many other advantages afforded by oil.

Labour and Maintenance.

Next in importance to cost and supply comes the Labour problem. The saving in labour effected by oil is not only confined to work in the boiler-house. It begins in the producing fields, where liquid fuel is obtained by the exertion of far less manual labour than is required to win coal. Moreover, the difficulty of winning coal increases as the underground workings are extended.

The amount of labour required to transport the oil from the producing fields to the consumer is also considerably less than with any other type of fuel, whilst the task of distributing the fuel about a large works is at once easy and convenient.

The reason for this great difference in the relative costs of handling the two types of fuel is found in the greater scope which oil affords for the utilisation of simple mechanical appliances.

Pumps and pipe lines replace picks, shovels, and wheelbarrows, whilst in many cases *pipe lines have replaced an entire railway system!*

From experience, it is known that when a gang of men is employed to load coals on board ship from lighters the average rate of working is less than one ton per man per hour. Thus, it would require 35 men, working 2½ hours, to load 80 tons of coal.

Oil, on the other hand, can be pumped at the rate of 300 tons per hour.

In the boiler-house itself considerable reduction in staff is effected when oil replaces coal, and experience has proved that even the most inferior type of labour can obtain results with oil which could never be procured with coal.

In general, the boiler-house staff will be halved at least when changing to oil, and, in large plants, the reduction of personnel might be carried even further than this.

Thus, in very large establishments, a considerable saving in the wages bill must be credited to oil in arriving at a true comparison of the relative working costs of the two fuels.

The ease with which a large battery of oil-fired boilers can be maintained in commission, *working at full pressure*, by one or two attendants is an important factor in these days of industrial unrest.

There are industries in which temporary stoppage, or interruption, of steam production would have disastrous consequences upon some section of the works.

The sudden cessation of evaporation might interrupt costly and delicate processes, destroy hundreds of tons of valuable material, and, in a few instances, imperil the structure of the works itself.

The cost of boiler maintenance is not by any means such a heavy item with oil as with coal. Indeed, it has been shown that the life of a boiler is increased by at least seven years when it is converted to burn oil.

Moreover, the robust construction of modern oil burners and furnace fittings has reduced the cost of upkeep of these items to an almost negligible figure—amounting to no more than the occasional renewal of a small pipe connection or the replacement of a damaged filter basket.

The outlay in tools is also a very small item, the only

tool really necessary being a long rake or slice for breaking up carbon formations in the furnace.

Against this, in the case of coal, must be put the expense of constantly renewing shovels and fire-bars—both very heavy items in coal-fired plants.

Control over Fires.

The fires of an oil-burning boiler are at all times under perfect control, and the steaming capacity of the boiler can always be adjusted to suit any reasonable variation of load.

This is not only a very great convenience, but it is also of great assistance in effecting economy.

There can be little doubt that much of the inefficiency of coal-fired boilers is due to absence of proper control over the fires.

The amount of fuel fed to the furnace is controlled by the shovelful, and, unless the fireman is a man of considerable experience and sound judgment, it will be impossible for him to regulate combustion to produce maximum economy.

This statement may, perhaps, call for some qualification, and the following digression on coal firing is, therefore, given :—

The most economical furnace is that which will burn all the fuel supplied, *with the least excess of air.*

Excess air cools the furnace, and considerably increases the heat loss to atmosphere.

An average sample lb. of coal requires about 12 lbs. of air for complete combustion, and when no excess air is present the furnace temperature is round about 5000° F.

For any given quantity of excess air the furnace temperature remains constant.

Thus, when 18 lbs. of air are supplied per lb. of coal, the excess is 50%, and the furnace temperature drops to 2700° F.

Every additional lb. of excess air beyond this figure is responsible for a further drop of about 100° F. of furnace temperature.

Thus, with 30 lbs. of air supplied per lb. of coal, the furnace temperature is only 1700° F.

In practice, only the most improved type of boiler can work with so low an excess of air as 50% (18 lbs. of air per lb. of coal), and then only in the hands of the most skilful firemen.

A more usual figure in land installations, working under natural draught conditions, is 30 lbs. to 35 lbs. of air per lb. of coal.

The effect of the presence of excess air is twofold, and arises mainly from cooling of the furnace.

In the first place, a coal-fired furnace cannot use the more volatile constituents of the coal to the best advantage; and, in the second place, the efficiency of radiation falls off very rapidly with reduction in furnace temperature.

The importance of maintaining a constant and adequate furnace temperature cannot be over-estimated, and to produce this condition demands the greatest nicety of judgment in regulating the supply of fuel.

The gases liberated during the initial stages of the combustion of coal will not ignite at a temperature below 900° F., and unless this degree can be maintained at all times, considerable quantities of unburnt fuel will be passed into the atmosphere at frequent intervals.

That this is no mere theoretical hypothesis is demonstrated by the practical difficulty of maintaining a clear chimney for any length of time with coal-fired boilers.

Wastage from this source can be mitigated to a large extent by keeping the fires bright and clean, and by feeding the fuel in small quantities at frequent intervals. This practice will insure that the furnace temperature is always sufficient to ignite the volatile constituents of the coal as soon as they become liberated; but, as will be shewn presently, another evil is introduced which has almost as destructive an influence upon efficiency as the error we set out to correct.

The necessity for feeding the fuel in small quantities naturally means that the fire doors must be opened at frequent intervals. Each time this is done a cold blast of air rushes across the furnace, playing havoc with efficiency and endangering the structure of the boiler.

Moreover, to feed coal to a boiler furnace in sufficiently small quantities to ensure proper combustion is a feat which can hardly be performed by human agency. Mechanical stoking may help to reduce the difficulties, but it is now generally conceded that these appliances are not economical when applied to plants of less than 500 horse-power.

At all events, the fact that the most carefully designed and the most skilfully operated coal-burning boilers cannot in practice be made to yield working efficiencies higher than 70%, whilst the general run of efficiencies obtained from the boiler plants connected with industrial undertakings in Great Britain is only from 50 to 60%, is sufficient indication that there is plenty of room for improvement here.

With oil, the average efficiency obtained with plants working under normal conditions is never much below 75%.

This high efficiency is the result of having the fuel under proper control, so that only sufficient is fed to the furnace to meet the needs of the moment; whilst the air supply can be so nicely adjusted as to enable the hall-mark of economy—a clear chimney—to be obtained at all times, and by even the most unskilful labour.

Further, the rapidity with which a proper furnace temperature can be attained is limited only by consideration for the safety of the boiler structure, and, when once attained, this temperature can be maintained over long periods with perfect regularity.

In short, the practice of burning solid fuel in a boiler furnace is wasteful in the highest degree, notwithstanding any mechanical aid which might be introduced to obtain better fuel distribution.

The only sane, scientific, and economical method of burning coal is in liquid form.

One ton of gas coal containing about 30% of volatile matter, if distilled at low temperatures (about 450° F.), would yield about 14 cwt. of coalite breeze, 20 gallons of tar oil, sp. gr. about 1·075, and from 3000 to 5000 feet cubic of gas.

The coalite breeze is quite suitable for domestic heating and cooking purposes, the tar oil is a first-class fuel for oil-burning boilers, and the gas possesses high illuminating value besides being available for power production.

The burning of tar oil in bulk under boilers first became a practical success about the year 1871, whilst atomization of this fuel was accomplished for the first time as far back as 1879.

Fire Hazards.

When oil first began to loom large as a serious competitor in the fuel markets of the world, much was made of the terrible danger of fire by those whose interests were opposed to the widespread adoption of the new fuel.

To-day, we cannot fail to realise that one of the most astonishing features of the development of oil fuel has been immunity from fire.

Atmospheric electrical discharges during stormy weather are said to be responsible for most of the serious outbreaks of fire amongst oil storage depots in the United States of America, whilst a few have been attributed to discharges of static electricity from the surfaces of pipes and appliances placed near to the tanks.

It must be remembered, however, that American practice for long countenanced the use of wooden roofs to cover storage tanks. Needless to say, this greatly increased the chances of fire. Modern practice demands that such tanks be constructed throughout of steel or reinforced concrete, whilst great care is now taken to ensure that all joints are perfectly tight against fluid or vapour leakage.

Perhaps the main reason why oil can be handled with such perfect immunity to fire is due to the fact that oil cannot ignite spontaneously under normal conditions of temperature and pressure.

Oil can only be ignited by actual contact with a naked flame under all ordinary conditions of temperature and pressure.

Coal, on the other hand, requires very careful handling, when stored in large quantities, to prevent spontaneous ignition, and, despite all precautions, outbreaks of fire

in bunker spaces are not by any means infrequent. Coal possesses the property, in common with many other solids, of condensing large quantities of gases, such as ammonia, sulphuric acid, carbonic acid, and oxygen, upon its surfaces. Given certain atmospheric conditions, this process may be greatly accelerated and become manifest in a gradual increase in the temperature of the coal pile, due to the absorption of the latent heat of condensation.

Unless steps are taken to break up the pile, spontaneous ignition will ultimately take place.

Oil, on the contrary, evaporates when exposed to the atmosphere. This results in a reduction of temperature, due to the withdrawal of the latent heat of vapourisation from the oil.

Sufficient insurance against fire can be obtained by insisting upon regular and systematic inspection of plant for leakage.

Oil tanks and pipe lines should be inspected by a responsible member of the staff at regular intervals, and immediate steps must be taken to remedy defects.

In the event of fire, the following methods are available for combating the outbreak :—

Water is useful for small outbreaks, but is not recommended for general use, especially in cases where the quantity of oil to be protected is large. Unless the fire is extinguished by the first cooling effect of the water, there is imminent danger of the burning oil being floated away on the surface of the water. This will not only place the fire hopelessly out of control, but will also seriously endanger surrounding property.

Steam is a much better medium. It is essential, however, that the tanks remain properly steam-tight, and,

for this reason, steam cannot be accepted as an infallible protective agent.

Frothy Mixtures represent the latest development in fire-fighting appliances for large oil storage depots.

They have given excellent results in America, and, recently, a special committee recommended the adoption of this system for Marine purposes.

Two solutions, one of sodium carbonate to which some frothing material has been added, the other of alum and sulphuric acid, are stored in separate tanks close to the storage tanks.

In the event of fire, the two mixtures are conveyed along separate pipes to a mixing chamber at the side of the burning tank. Here they are mixed in correct proportions, and a heavy frothing mixture is produced which rolls over the surface of the burning oil.

The bicarbonate gives carbon dioxide, which stifles the fire, whilst the frothy nature of the mixture prevents the burning oil from rising to the surface.

For dealing with small external fires such as might break out in the boiler-house, a good supply of sand should be kept at hand.

Storage.

Oil fuel can be stored in 50% of the space occupied by the equivalent amount of coal. This represents a direct saving in storage space, which will be of importance where land is scarce.

There are also considerable savings in the labour and plant required for the handling and distribution of the fuel, whilst the losses due to spillage and other forms of leakage are negligible.

Oil improves with age, and so large quantities can be stored without any deterioration of heating value. This will not only reduce the cost incurred by frequent transport, but will also enable large reserves of fuel to be kept in hand.

Coal, on the other hand, loses about 25% of its heating value when kept for two or three years, and it must be remembered that large piles of coal require very careful attention to prevent spontaneous ignition.

Cleanliness.

The industries in which the matter of cleanliness will, no doubt, be of special interest are those using boilers to produce steam for heating purposes as well as for power.

Absence of dust and soot is a distinct advantage in confectionery works, food factories, laundries, and sanatoriums.

In food factories, steam is used for a great variety of cooking purposes as well as for power, and so whatever economy can be secured is well worth while.

At a food factory recently visited by the writer it was observed that, intermixed with the carriage and trucking of the most delicate foodstuffs, there were regular processions of wheelbarrows laden with small coal for the boilers—this coal being drawn from large shallow bins, themselves a prolific cause of flying dust and grime.

On a windy day this meant disaster to quite an appreciable quantity of the commodities during transport from one process room to another.

The liability to contamination can be wholly eliminated by adopting oil fuel. This fuel is conveyed from completely enclosed storage tanks to the boilers by pipe

lines. There is therefore no possibility of contamination due to contact with the fuel as it passes from storage to the boilers. Neither need there be any contamination by particles of soot and grit escaping from the chimney as a result of bad combustion.

In short, when coal is used in factories of this description someone has to pay for the uncleanliness of the process.

If the manufacturer is honest he will incur heavy loss of raw material, and this loss should be credited to oil when comparing the relative costs of operation of coal and oil.

In food factories *absolute* cleanliness is essential for the maintenance of purity of the products.

Yet in many such factories the importance of cleanliness in the boiler-house is entirely disregarded, although great care is taken to maintain all other departments scrupulously clean.

This is rather like the policy of shutting one's front door securely and leaving the window wide open.

Again, in factories using steam for both power and heating purposes, there is considerable attraction about oil as a fuel, considered from the point that there is no ebb and flow of pressure. Variations in pressure often spell disaster to the boiling processes, so important to the successful production of confectionery and foodstuffs.

With oil, not only is this disability removed, and constant pressure, which means steady cooking temperature, assured, but it should also be remembered that oil confers upon the user the greatest working economy in the operation and upkeep of steaming plants, which is the opportunity to maintain his boilers at full pressure.

There yet remains one type of steaming plant to be considered before closing this part of the subject.

Oil fuel is probably the only agent which can be successfully employed as a stand-by fuel for boilers using factory waste.

Sawmills and wood-working factories are examples of this class.

Sawdust and shavings can be used as the staple fuel for the boilers, but, in the event of an interruption in the supply, the oil can be brought into service *at once*.

Some modification to the ordinary type of furnace is, of course, necessary in order to make it available for this special duty.

Sawdust and other light but bulky fuels cannot be burned successfully in the ordinary horizontal grate. The material packs too closely to permit of proper combustion, so that the best type of grate to use is an inclined, or "stepped," grate, with the oil burner placed at the top.

Wood contains a large percentage of oxygen, and so only a small grate is required, although the bulky character of the fuel demands large capacity inside the furnace. These conditions are quite compatible with the requirements for burning oil.

The "stepped" grate consists of a series of slotted bars arranged to form an incline.

Air is introduced through the slots, which ensures a fairly even distribution of air amongst the fuel.

The ash gradually falls to the bottom of the slope, and may be removed by withdrawing a sliding plate in the bottom of the furnace, which allows the ash to fall into the ashpit.

With regard to the classes of oil which may be used

as fuel for raising steam, the following is a brief abstract from the Admiralty specification for oil fuel for the Navy :—

" The oil fuel supplied shall consist of liquid hydrocarbons, and may be either (a) shale oil or (b) petroleum, as may be required ; or (c) a distillate or residual product of petroleum ; and shall comply with the Admiralty requirements as regards flash-point, fluidity at low temperatures, percentage of sulphur, presence of water, acidity, and freedom from impurities.

" The flash-point shall not be lower than 175° F., close test—Abel or Pensky-Marten's. The proportion of sulphur contained in the oil shall not exceed 3·00%. The oil fuel supplied shall be as free as possible from acid, and in any case the quantity of acid must not exceed 0·05%, calculated as oleic acid, when tested by shaking up the oil with distilled water, and determining by titration with deci-normal alkali the amount of acid extracted by the water, methyl orange being used as indicator. The quantity of water delivered with the oil shall not exceed 0·5%.

" The viscosity of the oil supplied shall not exceed 2000 seconds for an outflow of 50 cubic centimetres at a temperature of 32° F., as determined by Sir Boverton Redwood's standard viscometer (Admiralty type for testing oil fuel).

" The oil supplied shall be free from earthy, carbonaceous, or fibrous matter, or other impurities which are likely to choke the burners."

Table 4 is a list of the principal fuel oils at present available, together with their most important properties.

TABLE 4.

TABLE OF FUEL OILS.

Oil.	Place of Origin.	Specific Gravity.	Composition per cent. by Weight.					Calorific Value B.T.U. per lb.	Lbs. of Air Theoretically Required per lb. of Oil.	Flash Point.	Lbs. of Water Theoretically Evaporated per lb. of Oil from and at 212° F.
			Carbon.	Hydrogen.	Oxygen.	Sulphur.	Nitrogen.				
Tar Oil.	Gasworks, &c.	1·05	82	7·6	10·4	*Nil.*	*Nil.*	15,810	11·63	...	16
Crude Petroleum.	Borneo, California, Mexico, Roumania, Caucasus, Java, Pennsylvania, Burma, Rangoon, Galicia.	·85 to ·95	82 to 88	11 to 13	*Nil* to 5	*Nil* to 3	*Nil.*	18,800 to 20,000	13·5 to 14.5	...	19½ to 21
Residuum and Petroleum Refuse.	America and Russia.	·93	87	11·8	1·2	*Nil.*	*Nil.*	19,000	14	...	20
Oil Fuel.	Borneo, California, Russia, Mexico, Texas, Argentine, Roumania, Java, Canada.	·86 to ·96	84 to 87	11 to 13	*Nil* to 3	*Nil* to 3	*Nil* to 0·6	18,800 to 19,800	13·5 to 14·5	160° F. to 250° F.	19½ to 21
Shale Oil.	Scotland, France.	·86	86	12	1	0·3	*Nil.*	18,500	14	125° F.	19
Refined Petroleum.	America and Russia.	·80	85·7	14	0·3	*Nil.*	*Nil.*	21,000	15	...	22

The facilities for the supply of oil fuel to consumers in Great Britain include three modes of transport. Works situated near to sea, river, or canal can be very conveniently and cheaply served by tank barge. Works situated inland, but having their own railway sidings, can be served by rail tank car, each car having a capacity of about 10 tons of fuel oil. Works situated inland and having no railway sidings can be served by road tank wagon.

Thus, it is seen that oil supplies can be obtained by works situated in almost any part of the country, and it should be noted that the prices quoted per ton of fuel oil include, as a rule, delivery charges to the purchaser's works.

The distribution of fuel oil in Great Britain is in the hands of three or four big Companies. There are large storage installations belonging to one or other of the Companies at Purfleet, Royal Albert Docks (London), Birkenhead, Hull, Sunderland, Eccles, Newcastle, Avonmouth, Plymouth, Belfast, and Dublin, as well as depôts and branches in every large town in the Kingdom.

It is not the province of this book to discuss the relative importance of the Companies, but it is essential to its utility that its readers should be informed where they can obtain supplies. A list of distributing Companies is therefore given *in alphabetical order*, with addresses of head offices, and the intending purchaser is advised to write to all of them stating his requirements. It might be, for instance, that one Company may happen to be better able to deal with an enquiry from a particular district at the time of writing. At all events, the figures given in the book cannot be taken as fixed; the price of oil varies, like the price of all other commodities, according to the

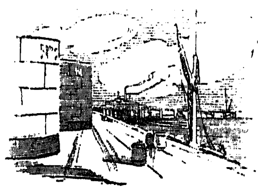
state of the market. Up-to-date quotations are then necessary.

ANGLO-AMERICAN OIL CO., LTD., 36-38 Queen Anne's Gate, Westminster, S.W. 1.

BRITISH PETROLEUM CO., LTD., 22 Fenchurch Street, E.C. 3.

THE SCOTTISH OIL AGENCY, LTD., 40 St. Vincent Place, Glasgow.

SHELL-MEX LTD., Victory House, Kingsway, London, W.C. 2.



SECTION 2.

Oil Burning Equipment for Land Installations.

ONE result of the present high cost of coal has been to produce a considerable demand for information concerning the changes needed to convert existing coal-fired boilers to oil burning. The giving of such information is fraught with difficulties not altogether connected with the purely technical aspect of the problem. The question of expense occupies a prominent place in the answer.

It may be said at once, that if the best possible results are to be obtained from a boiler so converted, the total cost will include not only the cost of the oil-burning apparatus, but also an allowance for structural alterations to the boiler and its setting. This additional outlay will, in general, be amply repaid in more economical working and in greatly increased steaming capacity.

Throughout this section particular attention will be given to the question of conversion, and it is hoped that the notes will prove of service to all who are contemplating such a change.

Fig. 33 shews a general arrangement of a land installation, comprising a Cochran Boiler equipped with the Kermode steam jet system of burning oil.

The oil is stored in a large settling tank, so called because it permits any water which is present in the oil to settle to the bottom and be drained off. This process of separation is assisted by steam-heating coils, and the accumulation of water is visible in gauge glasses fitted on the front of

the tank. This is recommended as good practice; but oil may be stored in any other form of tank, or even poured directly from barrels into the service tank.

The oil flows from the settling tank to a smaller service tank. The inlet to the service tank is through a gauze filter, which serves to remove particles of dirt which would otherwise get into the burner passages and choke them. The service tank also contains a steam-heating coil to maintain a steady flow of oil by reducing viscosity.

The service tank should be placed several feet above the burners in order to give sufficient head to produce a ready flow of oil. No pressure pump is necessary, the oil being fed entirely by gravity.

Steam is the atomizing agent, the supply being taken from an independent stop valve on the boiler top. The steam is superheated before it reaches the burners—an important detail which will be referred to again further on.

The flow of oil and steam is regulated by stop valves placed conveniently near to the burners.

The important matters of water separation, oil filtration, and heating have been dealt with at length in the Marine Section, and so will be passed over here. We will commence a detailed consideration of each item of a Land Installation with the Burners.

Burners.

Steam jet atomizers enjoy almost universal favour for land installations. In this regard, land practice has fallen behind marine practice, where, owing to the urgent necessity for economising in fresh water, the more economical pressure jet burner is now employed, to the exclusion of all others.

The principal reason for the continued employment of steam as an atomizing agent on land is found in the simplification of apparatus obtained, due to the absence of pressure pumps and oil heaters.

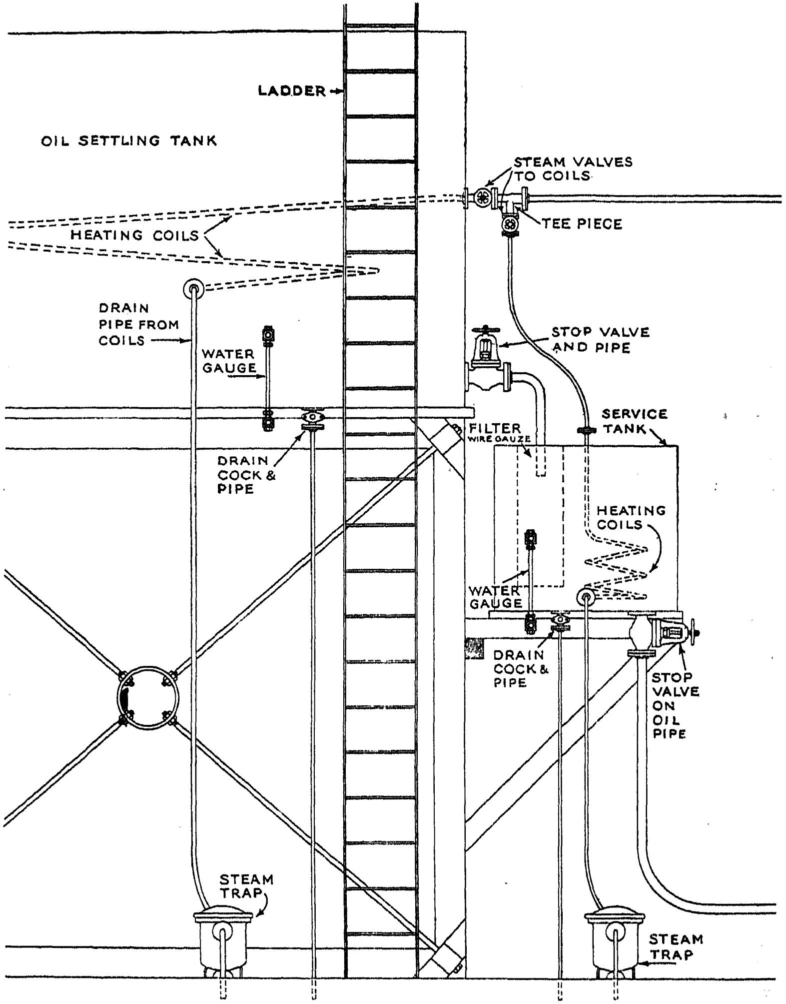
It is now generally recognised, however, from extensive experience, both on land and at sea, that much greater economy is obtained with pressure atomizers.

Figures obtained from recent tests shew that, with steam atomizing, the oil consumption was 10 per cent. more than with pressure atomizers.

Other factors which count seriously against steam as an atomizing agent are—a loss of 5 per cent. of the total boiler evaporation due to the utilisation of this amount of steam for atomizing purposes; a direct loss of heat to atmosphere due to the increased specific heat of the waste gases; and a reduction in the furnace capacity available for combustion due to the presence of steam, which remains inert during the process of combustion.

It should also be noticed that the 5 per cent. reduction in the available evaporative capacity of the boiler does not represent the total fuel loss from this cause. It also means that in a boiler evaporating, say, 1000 lbs. of water per hour, 5 per cent. (or 50 lbs.) of make-up feed must be supplied per hour, *i.e.*, 8400 lbs. per week.

In localities where water is cheap this item might not have much weight, but it must not be forgotten that every additional pound of fresh water introduced into the boiler adds to the amount of scale deposited on the heating surfaces. Thus, the practice of pumping large quantities of make-up feed is bound to reduce the efficiency of the boiler, and render more frequent cleaning necessary.



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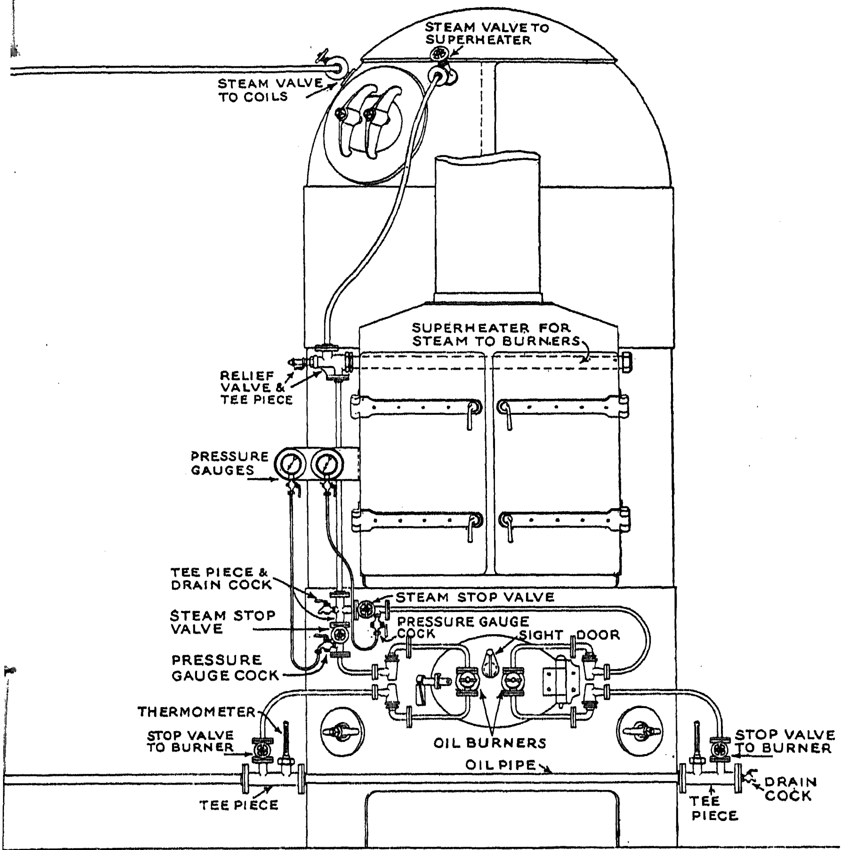
DIAGRAMMATIC ARRANGEMENT OF A COCHRAN BOILER ON



RE 33.

AND FITTED WITH KERMODE'S PATENT STEAM JET BURNERS.

The importance of superheating the steam used for atomizing has already been mentioned. Superheating is necessary to prevent the possibility of water being blown into the furnace through the burner. Cases could be cited in which boilers equipped with steam atomizers, but with no superheater, could not be started up because the jet obtained from the burners was largely composed of water.

Again, the corrosive action of the water spray used for cooling exhaust gases after expansion into steel drums is well known. So long as the steam is dry no great harm will be done, but should the steam be so wet that particles of water are deposited on the surfaces of the steel plates, trouble will at once begin.

The introduction of water into a steel drum containing carbon dioxide gas, for example, results in the formation of a weak solution of carbonic acid, which immediately attacks the metallic surfaces.

In the case of an oil-fired furnace, this action is further increased due to the presence of sulphur in the oil. The sulphur dioxide formed during combustion combines with any moisture which is present to form sulphuric acid—an highly corrosive fluid.

Thus, the importance of admitting only dry steam to the furnace is essential to the preservation of the external surfaces. The only sure means of fulfilling this requirement is to fit a superheater.

Messrs Cochran install a superheater in the smokebox of all boilers fitted with steam atomizing oil-burning equipment.

Fig. 34 shews twenty-six different types of oil burner which have been tried in practice.

These can be divided into six principal groups :—

(A) Drooling Burners, in which the oil dribbles down on to a steam or air jet and is blown into a fine spray ;

(B) Atomizing Burners, in which oil is picked up by a steam or air jet and carried into the furnace as a fine spray ;

(C) Chamber Burners, in which the oil mixes with a steam or air jet in the body of the burner, and is pulverised during the rapid expansion of the steam or air at exit ;

(D) Injection Burners, which are similar in principle to the last group, except that the expansion of the steam or air is modified by a convergent conical nozzle at exit ;

(E) Projection Burners, in which the oil is pumped to suitable exit holes, where it is picked up by a steam or air jet, which projects it into the furnace ;

(F) Pressure Burners, which dispense with an atomizing agent.

Each group appears in several modified forms, according to the shape of the spray.

Experience shews that, with steam or air as atomizing agents, any of the types of burner illustrated will produce a satisfactory spray ; and in making a selection the following points must be considered.

Whether the shape and size of spray is suitable for the furnace in which the burner is to be installed.

Whether all parts of the burner are readily accessible for cleaning.

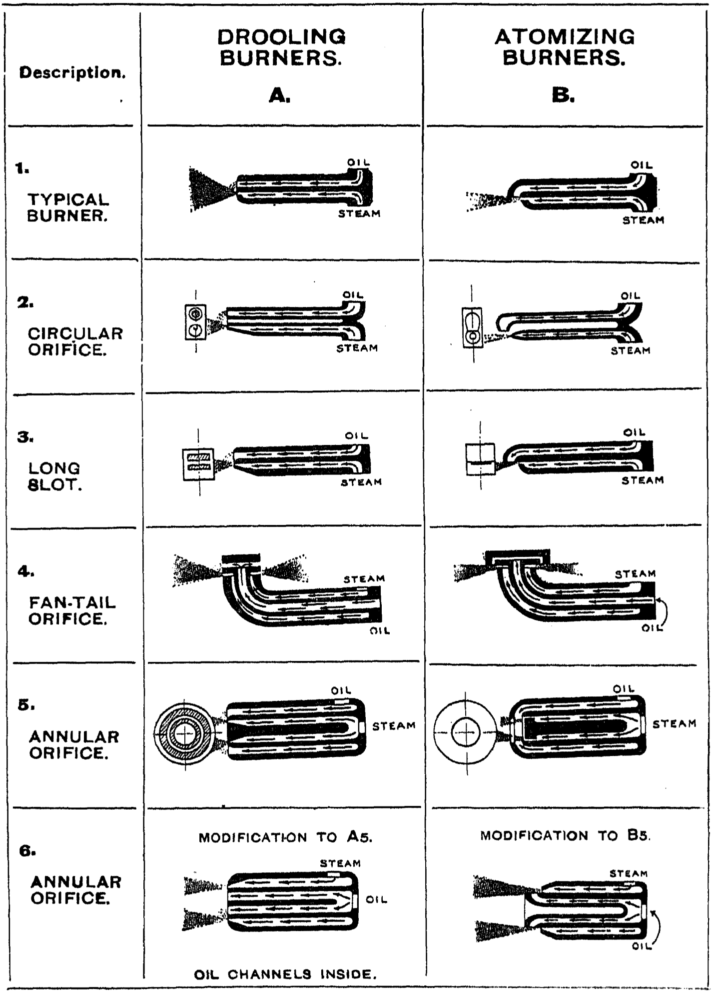


FIGURE 34.

TYPES OF OIL BURNER.

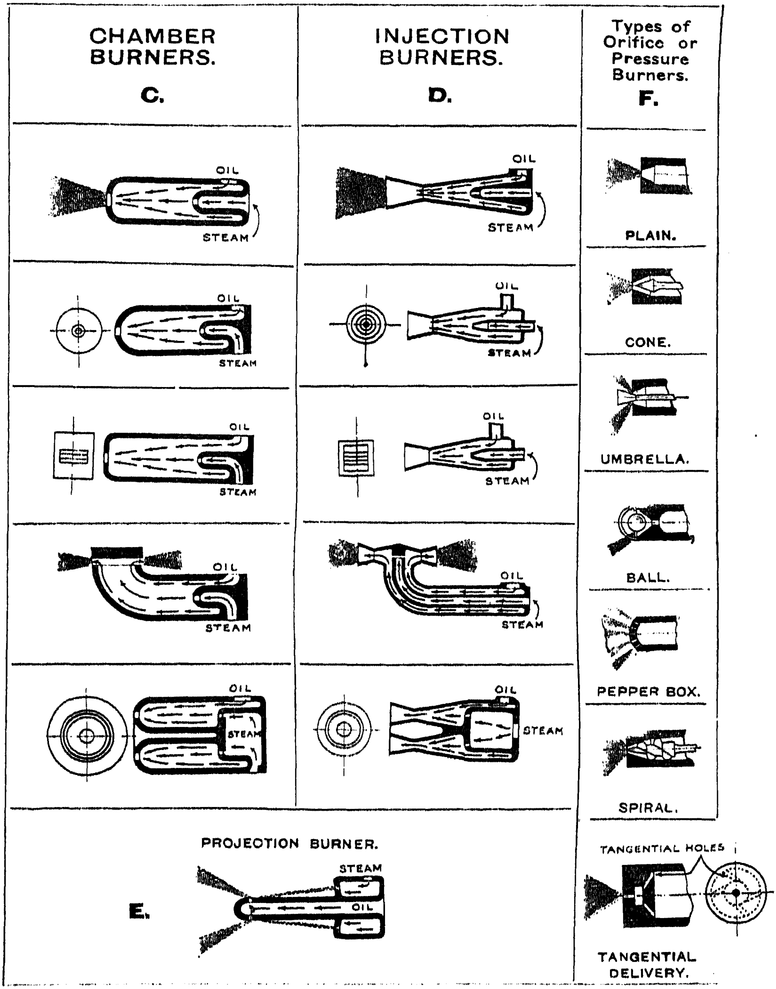


FIGURE 34.
TYPES OF OIL BURNER.

Whether the burner is of robust construction, and whether provision has been made for the renewal of parts (such as the burner tip), likely to wear out.

Whether the oil passages are large and direct, in order to prevent choking and enable low fluid pressures to be used.

Whether provision has been made for regulating output without excessive mechanical complication.

Several types of pressure jet burner are shewn. The most elementary type consists of a single hole drilled through the burner tip. To obtain proper atomization with this design, small orifices and high pressures are required.

In practice, pressure burners with spiral passages or tangential holes in the tip have proved most satisfactory, giving the largest output, with moderate oil pressures.

The main point to be decided in selecting a burner for land installations is to choose between steam and pressure jet atomizers.

If initial expenditure must be kept down, steam atomizers are undoubtedly the cheaper to install.

But this rather doubtful economy results in a permanent addition of at least 10 per cent. to the fuel bill, and a reduction in the available evaporative capacity of the boiler of 5 per cent.

Steam atomizers are frequently fitted to boilers consuming less than 150 lbs. of oil per hour, in order to have a larger exit orifice in the burner than would be practicable with pressure atomization.

Having decided between steam and pressure atomizers, the selection of a suitable burner is best left to the boiler-makers themselves, who, from extensive experience, will

generally be in a position to recommend a type of burner which is best suited to the requirements of their particular design of boiler.

Furnaces.

Ample volume is the first requirement of an efficient oil-burning furnace. This is necessary—first, to give sufficient time for combustion, so that the waste gases do not leave the boiler containing portions of unburnt or partially burnt fuel; and second, to assist the burners by providing plenty of room for atomization.

With restricted furnace capacity, the danger is that drops of liquid oil may be deposited on the comparatively cold surfaces of the plates.

The shape of the furnace and combustion chamber should be arranged to give an easy passage for the burning gases. Pockets and obstructions should be avoided at all costs, because they serve to prevent free access of air to all parts of the combustion space, and because they might deflect portions of the flame on to isolated sections of the furnace plates, with consequent danger of serious local heating.

The importance of arranging the furnace and combustion chamber in relation to the rest of the boiler so that proper water circulation is obtained must also be kept in mind.

A spherical surface encloses the maximum volume obtainable with a given surface. Hence, for a given heating surface, the maximum possible furnace volume will be obtained if the spherical form is adopted. This shape would also offer other advantages, such as easy passage for the gases and great structural strength.

The furnace of a Cochran Boiler is an example of sound design in this respect. This furnace is hemispherical, and so exemplifies a very good practical solution embodying the factors set out above.

Under normal steaming conditions, the furnace heating surface is the most efficient of the heat-transmitting surfaces. Temperature measurements from boilers actually in commission shew that approximately half the total heat reaches the water through the sides of the furnace and combustion chamber.

In the Cochran Boiler, therefore, the best possible use is made of this surface by adopting a hemispherical furnace crown, thus obtaining the maximum available volume for combustion. For this reason, and also because of the ease with which the incoming air can reach all parts of the combustion space, this design of furnace is eminently suitable for burning oil.

Coming now to consider the changes which must be made to the furnace when converting a boiler to oil burning, we may say at once that a furnace which has given good results with coal will not, as a rule, have sufficient cubic capacity to yield the best possible results with oil.

The additional outlay required to provide the extra volume necessary for burning oil is well worth while; and, unless the matter of first cost is of paramount importance, one would be ill-advised to save a trifle at the expense of placing such a severe handicap upon the capabilities of the plant.

Perhaps the most noticeable difference between furnaces of ample capacity and those which are restricted is found in the quantity of oil which can be burnt in a given time.

In this connection, it must not be thought that the quantity of oil which can be burnt in a given time under a particular size of boiler is simply a question of burner efficiency.

Burner efficiency has little, if anything at all, to do with the matter ; it is almost entirely a question of furnace capacity.

En passant, it has already been indicated that with steam atomization part of the combustion space is occupied by steam, which takes no part in the actual combustion of the fuel. Hence, a furnace of given capacity will burn more oil and generate more steam with pressure atomizers than with steam atomizers, because with pressure atomization the whole of the furnace volume is available for combustion.

In the Cochran Boiler, extra furnace volume can be obtained by extending the ashpit and mounting the boiler on a pedestal, when firing is done exclusively through the extended portion.

In cases where the existing boiler setting cannot be disturbed, or where it is necessary to keep down the cost of conversion, the original boiler can be stripped of its coal-burning equipment and oil burners can be supplied to fire through the firehole, without disturbing the existing setting.

It must be remembered, however, that when this is done the purchaser will have to be content with working his boiler easily.

In designing a boiler, the heating surface is proportioned and arranged to give maximum economy with a certain specific rate of evaporation.

This rate of evaporation is usually referred to as " easy steaming," and represents the figure at which good, all-round economy will be obtained.

The duty of the boilers can be increased by forcing the draught. When this is done more fuel is burned per square foot of grate area, and, within limits, the total evaporation of the boilers increases. But—and this is the point which must always be kept in mind—*the increase in evaporation is not proportional to the increase in fuel consumption.*

More fuel is required per lb. of water evaporated, due to the increased loss of heat to atmosphere.

In short, the extent to which the normal evaporative power of a boiler can be increased is strictly limited, and depends, amongst other things, upon the ability of the heating surfaces to transmit the increased amount of heat.

Moreover, the wider temperature ranges introduced when a boiler is forced, increase the stresses on the structure, and so the first sign of excessive forcing is sometimes found in water leakage, generally from the tube ends.

With oil, owing to the ease with which the air supply can be regulated, proper combustion can be maintained with a very much smaller excess of air than with coal. This means, that the heat loss to atmosphere in the case of an oil-fired boiler working at a high rate of evaporation is not nearly so great as in the case of the same boiler using coal under similar conditions. Further, the process of combustion itself is so steady that dangerous fluctuations of temperature are not likely to be encountered when oil is burned.

This means, then, that the evaporation of a boiler may be increased when oil is substituted for coal without any fear of a drop in efficiency, or of damage to the boiler from over-stressing of material.

But it must be again emphasised that this increase of

duty can only be obtained by an increase in the volume of the combustion space.

When a battery of boilers is converted to burn oil, the original evaporation can be obtained, after conversion, with a reduced number of boilers. In practice, advantage has been taken of this to use the boilers placed out of commission as oil storage tanks. Care must be taken, of course, to block up flues and disconnect all steam and water pipes.

By adopting this course, oil storage can be provided at minimum cost.

To sum up, we have :—

1. When converting a boiler to burn oil, no alteration to existing furnaces or boiler setting need be made if the purchaser is content to accept the same " easy steaming " evaporation as he obtained when burning coal;

2. When a boiler is converted to burn oil, its evaporation can be increased to give the " maximum " evaporation quoted by the makers, without loss of efficiency; but

3. Maximum evaporation, with oil, can only be obtained by increasing the volume of the combustion space.

We will now consider a few examples of boiler furnaces arranged for burning oil.

Fig. 35 shews a Cochran Boiler arranged for oil firing exclusively through the firehole.

This represents the simplest and cheapest arrangement for boilers which are converted from burning coal.

The alterations required are :—To remove the fire-bars, grate ring, and bearers; to cover the foundation inside the

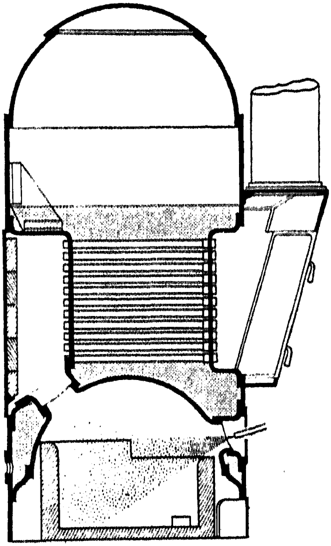


FIGURE 35.

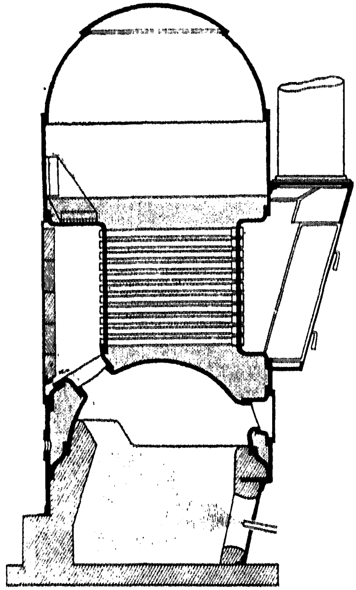


FIGURE 36.

furnace with a layer of firebrick; and to build up a circular wall of firebrick, which serves to protect the lower seams of the boiler, and enables sufficient heat to be retained in the furnace to re-light the burners should a momentary interruption of the flow of oil occur.

We have already discussed the matter of the evaporative power of a boiler arranged in this manner.

Fig. 36 shews a Cochran Boiler arranged for oil-firing exclusively through the "ashpit."

This is a much better arrangement than the last, and, in fact, represents the best possible mounting for land purposes.

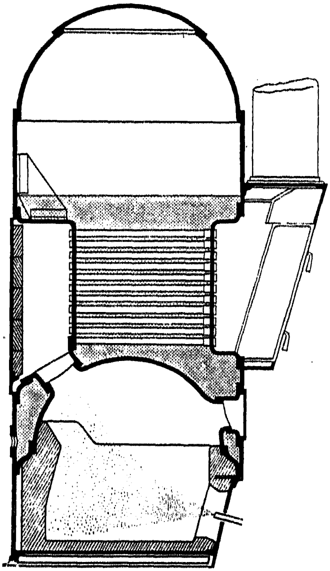


FIGURE 37.

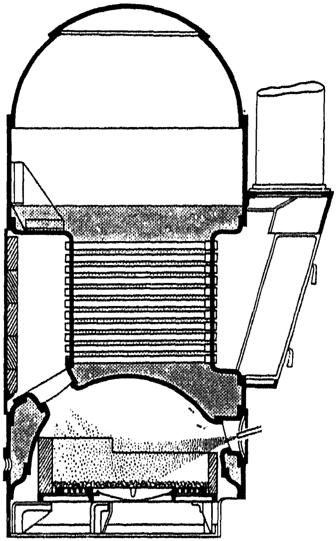


FIGURE 38.

Plenty of space is available inside the furnace for combustion, enabling the greatest possible duty to be obtained.

The boiler is mounted on a low ring of firebrick, so arranged that plenty of protection is given to the bottom circumferential seams.

The air supply is regulated by doors or louvres, arranged to suit the particular type of burner used.

Fig. 37 shews a similar arrangement to the last, except that a modification to the foundation has been introduced to make this type available for use on board ship.

To prevent undue heating of the deck, a horizontal

plate is fitted a few inches from the deck, this plate being covered with firebrick inside the furnace as shewn in the sketch.

The air space so provided affords ample heat insulation.

An auxiliary air inlet, with sliding door for regulating the supply, is provided in the bottom plate.

Fig. 38 shows a type of furnace suitable for dealing with both liquid and solid fuels.

A cage grate, consisting of a cylindrical steel plate lined with firebrick, and provided with a set of cast-iron fire-bars upon which coal can be burnt, is fitted.

When running on oil alone, the fire-bars should be covered to the depth of a few inches with broken fire-brick.

This arrangement is an example of a compromise, and compromises seldom achieve unqualified success.

The grate is too high, and the cubic capacity is too small to enable good results to be obtained when burning oil. On the other hand, the grate area is restricted, and the grate itself is too low in relation to the firehole to enable it to be properly cleaned when burning coal.

Thus, in attempting to cater to the requirements of both oil and coal, justice cannot be done to either.

Happily, due to the increasing stability of the oil-fuel market, and to the confidence which is now placed in oil-burning apparatus, this type of furnace is gradually being displaced by the other arrangements described above. In any case, it should not be adopted unless conditions absolutely prohibit one or other of these schemes.

Draught.

The successful handling of an oil-burning installation demands very careful attention to the matter of air supply.

Some fuel oils require more air for complete combustion than others, and unless a proper range of adjustability of the air supply is provided, it will be impossible to obtain proper combustion with all grades of oil.

It has already been stated that the most efficient furnace is that which will consume all the fuel supplied with the least excess of air; but it is important to remember, that a *slight excess* is always to be preferred to a *deficiency* of air.

Deficient air should be avoided at all costs. The reason is, that when the least deficiency develops, the fuel is burnt to carbon monoxide instead of to carbon dioxide. The amount of heat liberated under the former condition is only one-third of that liberated under the latter condition.

Nearly all land installations are worked with natural draught, and the quantity of air supplied depends partly upon the dimensions of the chimney and partly upon the temperature at its base.

Theoretically, the highest efficiency is obtained with the lowest chimney temperature, due to the smaller amount of heat energy which is carried away in the waste gases.

In practice, however, in order to keep the chimney dimensions within workable limits, the temperature at the base is seldom less than 400° F.

Many rules have been proposed for obtaining the dimensions of the chimney. A few are founded on theoretical argument, but it must be admitted that the best results are obtained from formulæ which are, frankly, empirical.

From theory, we know that the height of the chimney determines the velocity of the gases—this being, roughly, proportional to the square root of the height.

Now, it is well known that the scrubbing action of gases flowing at relatively high velocities across the heating surfaces is, within limits, beneficial. Hence, from this aspect, a tall chimney is desirable.

On the other hand, the frictional resistance to flow increases very rapidly with velocity, so that here we have an argument against excessive height.

Generally speaking, the minimum height for a boiler chimney is fixed by the rules of local authorities, whilst the maximum height is determined by structural considerations.

The area of the chimney in conjunction with the velocity of the gases, determine the quantity of gas which can be passed in unit time.

Messrs Cochran, from extensive experience in these matters, recommend that, when converting one of their boilers to oil burning, the existing chimney be increased 20 per cent. in height and 25 per cent. in area.

This will enable the extra amount of air necessary for burning oil, due to its higher calorific value, to be passed, and will also ensure an adequate range of adjustability for meeting variations in the grade of fuel used and in the duty required from the boiler.

Before closing these remarks on the subject of draught, a few words on the methods of testing efficiency might not be out of place.

The only fair method of gauging the performance of oil burners or of oil-burning furnaces, is by flue gas analysis.

Evaporation trials afford a good indication of the overall efficiency of the steaming plant, but they are useless as a means of comparing the capabilities of burners and furnaces.

Poor evaporation results might be due to faulty boiler design.

As already stated, the amount of excess air supplied is the true test of the relative efficiencies of burners and furnaces.

With coal, the amount of excess air supplied is rarely less than 100 per cent., representing a fuel loss of about 20 per cent.

With oil, the amount of excess air is never more than 50 per cent., representing a fuel loss of not more than 5 per cent. from this cause.

In practice, the aim should always be to supply a *little more* air than what is necessary for complete combustion, rather than run the risk of having deficient air.

It is possible, with oil, to adjust the air supply to correspond very closely with the theoretical amount required for complete combustion. But this practice is not to be recommended, because, when sailing so near the wind, it is next to impossible to avoid crossing the line at intervals, and so reduce the amount of air supplied below that required for complete combustion.

When this happens, the fuel is burnt to carbon monoxide instead of to carbon dioxide, which means that only one-third of the available heat energy is liberated, the rest being carried away by the waste gases.

Excess air should be kept to a minimum, but deficient air must be avoided at all costs.

Storage Tanks.

Generally speaking, oil fuel storage installations consist of one or more tanks constructed of iron, steel, or reinforced concrete. The material selected in any particular case will depend upon local conditions, capacity required, initial cost, and the individual ideas of the purchaser. Further, the tanks may be located underground, at ground level, or elevated, as found most convenient.

For storing large quantities of oil, reinforced concrete tanks are undoubtedly the cheapest to install, but, to ensure success, the work of construction must be placed in the hands of reinforced concrete specialists who possess the necessary experience in this class of work.

Vertical iron or steel tanks, riveted together, and carried upon substantial foundations at ground level with proper provision for settlement, are also suitable for storing large quantities of oil.

Fig. 39 shews a tank of this description, build by Messrs Newton, Chambers & Co., Ltd., of Sheffield, for storing 580 tons of fuel oil. This tank is 35 feet in diameter and 25 feet deep. A point of special interest in the design is the swinging suction pipe, which can be moved up or down by means of a small winch so as to draw off the oil from any level inside the tank. Thus, should any water or sediment accumulate at the bottom of the tank, the suction pipe can be moved up to a level where pure oil is drawn off.

Other points to notice are the substantial roof and the provision made for ventilation in the highest part of the tank.

This type of tank has been built in sizes as large as

200 feet in diameter and 40 feet deep, representing a total capacity of more than 30,000 tons of oil.

Old boiler shells make first-class storage tanks. The ends of the furnaces should be plated over, and holes should be cut in the furnace plates to give full capacity for oil

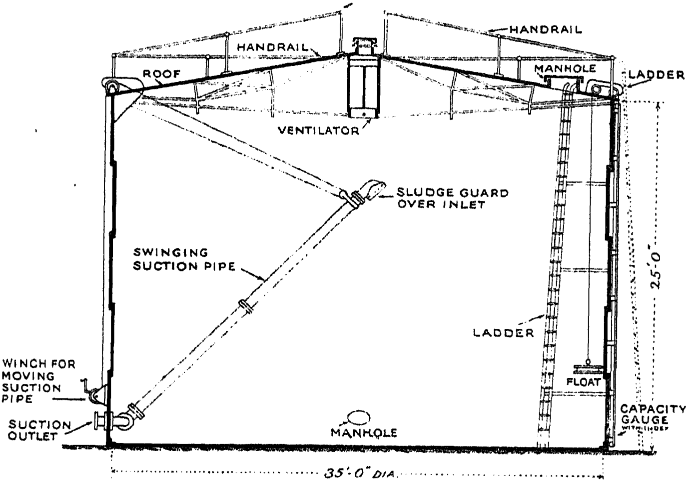


FIGURE 39.

TANK FOR STORING LARGE QUANTITIES OF OIL FUEL.

without removing the furnaces. This will not only save the expense of removal, but the furnaces will serve to stay the flat ends of the shell.

When old boiler shells are used for storage, it is advisable to test the seams for leakage by applying 30 lbs. per square inch hydraulic pressure.

Reinforced concrete is a very suitable material for the construction of underground tanks. This type of

tank can be built to hold very large quantities of oil, and may be constructed wholly of reinforced concrete, or it may consist of a steel tank supported in a concrete bed.

The principal difficulty with underground tanks is to detect and repair leakage; whilst the presence of settled water cannot be seen as easily as with exposed tanks.

Tanks of moderate capacity may be rectangular or cylindrical in shape, and may be built at ground level or be elevated on towers.

For locations where it is desired to make use of existing coal bunker space for oil storage, tanks can be constructed from sectional cast-iron or steel plates. These tanks can be made almost any shape to suit the available space without disturbing existing walls or doorways, and with the minimum outlay in structural alterations.

These plates can be obtained from the manufacturers in either cast-iron or mild steel, and with either internal or external flanges.

Cast-iron plates are naturally heavier than the pressed steel plates, but it is claimed that cast-iron is not subject to the rapid corrosion which wrought-iron or mild steel undergoes.

Plates with internal flanges give a better external appearance to the tank, but external flanges are easier to keep oil-tight, and for this reason are to be preferred for this class of tank.

The capacities available range up to 120 tons in the elevated types, and up to 700 tons in the case of tanks built at ground level.

Oil storage tanks should be placed as close to the boiler house as possible, in order to reduce the length of service piping. It is not advisable, however, to have large

quantities of oil closer to the boilers than 500 feet, on account of fire hazards.

Due regard must also be paid to the necessity for arranging the tanks so that they can be filled from rail tank car, tank barge, or road tank wagon, as most convenient.

A site which possesses good natural drainage is always to be preferred to one where drainage is poor.

Artificial drainage is not always easy to apply, and, in any case, would involve considerable additional expense.

There is, of course, the question of exposure to weather; but an exposed position with good natural drainage should always have preference over a sheltered position where drainage is bad.

An excellent example of the result of neglecting this highly important matter of drainage came under the notice of the writer recently.

A large horizontal cylindrical steel tank had been installed for oil storage purposes on a site which possessed no natural drainage, and no provision had been made for artificial drainage.

After the first heavy rains, the tank was found floating on the storm-water which had collected in the hollow ground surrounding its foundations. This not only damaged the foundations, but also severed all pipe connections on the tank, and so caused considerable loss of oil (with incidental serious risk of fire), and completely stopped the steaming plant served by the tank.

High ground should always be chosen for oil storage tank sites, not only because proper drainage is thereby obtained, but also because a certain head becomes available to assist the flow of oil from the tank.

Oil storage tanks must be perfectly oil-tight, and should be provided with a steel or iron roof capable of preventing the ingress of moisture and dirt. The roof must also be capable of retaining inflammable oil vapour, proper means for ventilation being provided in the correct place.

The fittings carried by storage tanks on land are substantially the same as for tanks on board ship, viz., sounding pipes (or float gauges), ventilating pipes, steam coils water drain pipes, and suction pipes.

The suction pipes should be arranged to draw from a level at least 1 foot above the bottom of the tank.

This will prevent settled water or sediment from being drawn into the oil pipes.

In large tanks the suction pipe is constructed so that it can be raised or lowered to draw off oil at any level, as shewn in Fig. 39.

All pipes draining oil from the tank must be so arranged as not to be capable under any circumstances of syphoning out any of the oil contained in the tank.

The ventilating pipes should terminate in a swan-neck to prevent admission of dirt or water, and a gauze screen should be fitted across the open end to prevent flames resulting from accidental ignition of the issuing vapours from striking back along the pipe into the tank.

Oil may be pumped into the tanks by steam pumps in the case of large installations, or semi-rotary hand pumps in the case of small plants.

Owing to the high flash-point of the oil used as fuel for steam boilers, no trouble need be anticipated due to the regulations of municipal authorities.

Occasionally, the insurance company may raise a query, but in most cases the matter can be settled by pointing

out the high flash-point of the oil to be stored, and the fact that there is no liability for spontaneous ignition to occur.

The regulations issued by municipal authorities apply to oils having a flash-point below 150 degrees F., and are chiefly intended to prevent the indiscriminate storage of light oils such as paraffin, kerosene, and of spirits such as petrol.

It may, however, save trouble at a later stage if a plan of the proposed storage installation is submitted to the local authorities for their approval before the work of erection is taken in hand.

Fire hazards are considerably reduced by constructing a ditch or moat all round the tanks, of sufficient capacity to be capable of retaining all the oil contained in the tanks.

In the event of oil leakage resulting from fire or damage to the tanks, the oil will simply flow into the ditch, and can do no further damage by spreading over adjacent buildings.

In all installations of storage tanks, sufficient capacity should be provided to carry in stock enough oil for at least 14 to 16 days' supply under normal working conditions.

In calculating the capacity of a tank, allow 38 cubic feet of oil at 60 degrees F. to the ton.

Extra capacity must be given to allow for expansion of the oil under changes of temperature.

Oil expands about 1 per cent. for every 25 degrees F. increase in temperature, hence an allowance of 5 per cent. extra volume in the tank would permit a temperature increase of 125 degrees F.

Tables 5 and 6 will be found useful in calculating tank capacities.

TABLE 5.

Quantity of Oil Consumed in 24 hours Steaming at Maximum Evaporation.

TONS.

Catalogue No. of Cochran Boilers.	Maximum Evaporation (Lbs. per Hour).	LBS. OF WATER EVAPORATED PER LB. OF OIL.							
		10	11	12	13	14	15	16	17
1	360	·385	·350	·321	·296	·275	·257	·241	·227
2	500	·534	·486	·446	·412	·383	·357	·334	·315
3	700	·750	·681	·623	·577	·538	·500	·469	·441
4	850	·909	·825	·757	·700	·650	·608	·568	·535
5	1000	1·07	·973	·891	·825	·766	·714	·668	·629
6	1100	1·18	1·07	·983	·906	·842	·785	·735	·694
7	1400	1·50	1·37	1·25	1·15	1·07	1·00	·940	·885
8	1520	1·63	1·48	1·36	1·25	1·16	1·00	1·02	·960
9	1760	1·89	1·72	1·57	1·45	1·35	1·26	1·18	1·11
10	2160	2·32	2·11	1·93	1·78	1·65	1·55	1·45	1·37
11	2500	2·68	2·44	2·24	2·06	1·92	1·78	1·68	1·57
12	2500	2·68	2·44	2·24	2·06	1·92	1·78	1·68	1·57
13	2500	2·68	2·44	2·24	2·06	1·92	1·78	1·68	1·57
14	2600	2·78	2·53	2·32	2·14	1·99	1·85	1·74	1·63
15	3100	3·32	3·02	2·76	2·55	2·37	2·21	2·07	1·95
16	3100	3·32	3·02	2·76	2·55	2·37	2·21	2·07	1·95
17	3300	3·54	3·22	2·95	2·72	2·53	2·36	2·21	2·08
18	3600	3·85	3·51	3·21	2·96	2·75	2·57	2·41	2·27
19	4000	4·29	3·90	3·57	3·30	3·06	2·85	2·68	2·52
20	4800	5·14	4·67	4·28	3·95	3·67	3·43	3·21	3·02
21	5700	6·10	5·55	5·09	4·70	4·36	4·07	3·82	3·59
22	6600	7·07	6·44	5·90	5·45	5·05	4·70	4·42	4·16

Table 6.

Capacity of Oil Storage Tanks.

TONS.

Length or Depth in Feet.	DIAMETER IN FEET.										
	5	10	20	30	40	50	60	70	80	90	100
5	2½	10	40	90	160	245	355	480	630	800	990
10	5	20	80	180	320	490	710	960	1260	1600	1980
15	7½	30	120	270	480	735	1065	1440	1890	2400	2970
20	10	40	160	360	640	980	1420	1920	2520	3200	3960
25	12½	50	200	450	800	1225	1775	2400	3150	4000	4950
30	15	60	240	540	960	1470	2130	2880	3780	4800	5940
35	17½	70	280	630	1120	1715	2485	3360	4410	5600	6930
40	20	80	320	720	1280	1960	2840	3840	5040	6400	7920

Calculated on the assumption that 1 Ton of Oil at 60° F. occupies 38 Cubic Feet.

Table 5 is a table showing the amount of oil consumed every 24 hours when working at various rates of evaporation.

Table 6 is a table shewing the capacity of oil storage tanks of various sizes.

Example 1 :—

An old boiler shell, 10 feet dia. by 20 feet long, is to be used for oil storage.

If the tank is to serve a boiler whose maximum hourly evaporation is 4000 lbs., estimate the number of days'

fuel supply which the tank will contain when the boiler is worked continuously at full duty.

Assume that 15 lbs. of water are evaporated per lb. of fuel.

From Table 5 we find the consumption of oil per 24 hours for this rate of evaporation to be 2·85 tons.

From Table 6 we find the capacity of this size of tank to be 40 tons.

Hence—

$$\left.\begin{array}{r}\text{Number of days' supply}\\ \text{stored in tank}\end{array}\right\} = \frac{40}{2\cdot85} = 14 \text{ days.}$$

EXAMPLE 2.

A boiler evaporates 850 lbs. of water per hour, and it is required to find the size of tank necessary for storing sufficient oil to supply fuel for 30 days' continuous running at full duty.

Assume that 14 lbs. of water are evaporated per lb. of fuel.

From Table 5 we find that the amount of oil consumed by this boiler in 24 hours is 0·65 ton.

Hence, in 30 days' continuous running at full duty, the amount of oil consumed will be

$$0\cdot65 \times 30 = 19\cdot5 \text{ tons.}$$

From Table 6 we find that a tank 10 feet dia. by 10 feet deep would be suitable.

Conclusion.

In conclusion, it is hoped that this little book will help to stimulate interest and inspire confidence in what is rapidly becoming one of the most important subjects of modern times.

If it is admitted that any advance in scientific knowledge is good in proportion to the amount of comfort which it brings to mankind, then oil as a fuel at sea or on land must be admitted to the front rank of human benefactions.

The admittance of oil to the stokeholds of our Merchant Service would sweep away for all time the dire necessity which sends men down to the sea in ships to sweat out their life and lungs in a fiery purgatory.

On land, oil is capable of doing much to relieve the drudgery of industrial and domestic routine.

In the laboratories of our Universities and Technical Colleges, the use of liquid fuel for firing experimental steam plants would enable research to be carried out under ideal conditions, without the care and anxiety which attends the use of solid fuel.

For domestic cooking and heating purposes, the cleanliness and convenience of liquid fuel are potent factors; and it is worth while mentioning in this connection that one of the largest hotels in London uses oil fuel exclusively, for all purposes.

Finally, the author wishes to thank the Firms whose names appear in the text, for permission to reproduce photographs and diagrams of their several specialties.

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